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Science for Tomorrow's World

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THE MACMILLAN SCIENCE SERIES

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J. DARRELL BARNARD
SCIENCE EDUCATION

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UNDER THE EDITORSHIP OF

SIDNEY SELTZER

SCIENCE FOR TOMORROW'S WORLD: 1, 2, 3, 4, 5, 6
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SCIENCE: A WAY TO SOLVE PROBLEMS 8
SCIENCE: A KEY TO THE FUTURE 9

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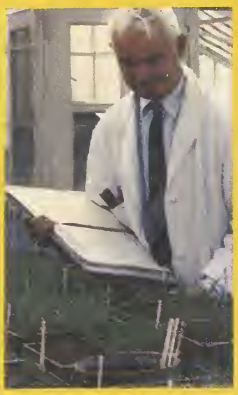

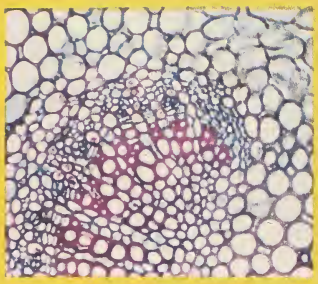

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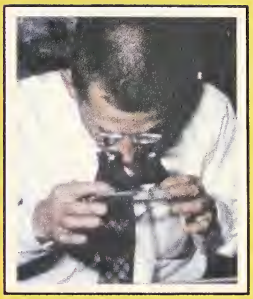

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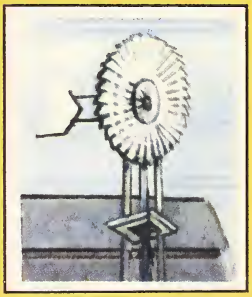

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The Scientist's Way

1

Comparing Things

Making Comparisons to Find Answers

The scientists on the opposite page are comparing things. So are the boys and girls. When you compare things, you show the ways in which things are like each other and the ways in which they are different. When you looked at the pictures, you compared something. Do you know what you compared?

Making Comparisons to Find Answers

A scientific **comparison** is a way of telling how things are alike and how they are different. One way the scientist finds out about things is by making comparisons.

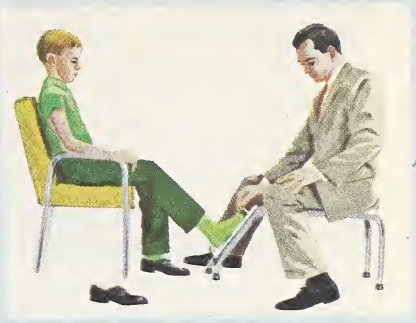
Look again at the pictures of the scientists. Some are using special tools. These special tools of scientists are called **instruments.** Can you name some of their instruments? Do you know why scientists use these instruments? Do you ever use any instruments to help you compare things? Why do you use them? Do you see any of these instruments in the pictures of boys and girls comparing things?

What Do You Compare?

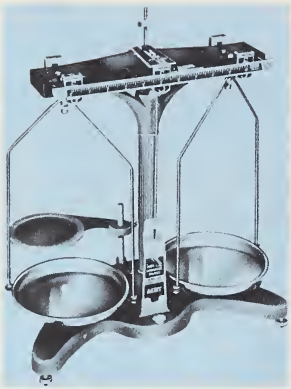
You compare many things. You compare how tall you are today with how tall you were a year ago. You compare how much you weigh today with how much you weighed last year. What else do you compare?

You get answers to many of your questions by comparing things. Scientists get answers to many of their questions by comparing things. They compare things by weighing them, timing them, testing them, and measuring them. These are some of the ways of scientists. The scientists write down everything they learn about the things they are comparing. It is always important to keep records.

When scientists do **experiments,** they make comparisons. They do experiments to find the answers to many of their questions. But there was a time when many people would not think of doing experiments to find the answers. Instead, they depended on the ideas



WAYS OF COMPARING THINGS



These are some of the tools of scientists. What might the scale and timer be used to compare? How might the test tubes be used to make a comparison?

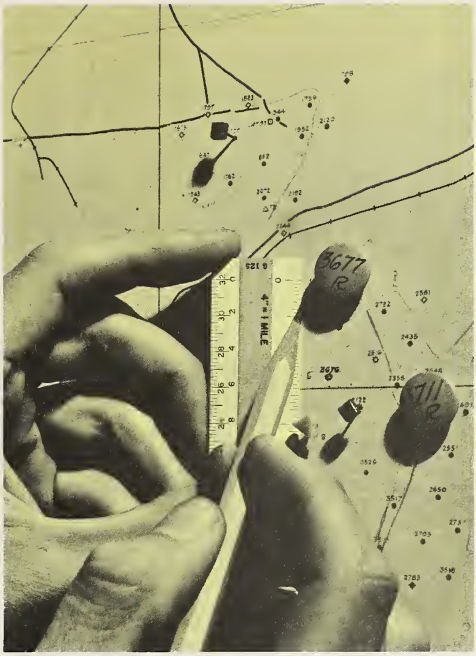
of wise men to give them the answers to their questions.

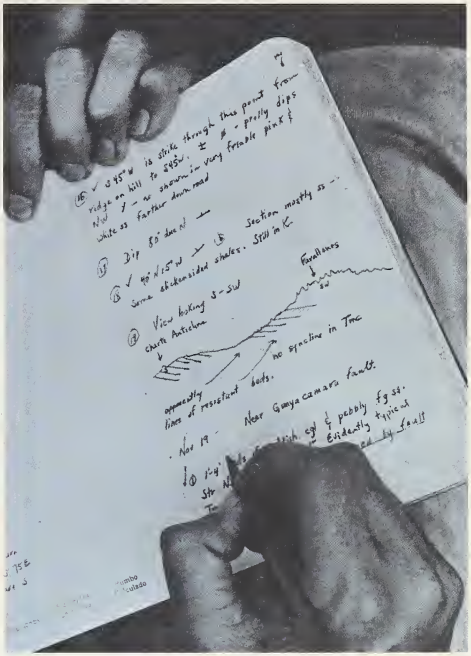
Aristotle (AR-iss-tot'l) was the most famous of these wise men. He lived in Greece over 2,000 years ago. Aristotle's ideas were thought to be the truth. For a long time, very few people ever questioned his ideas. People thought that ideas that everyone had believed for such a long time must be true.

Galileo Seeks Proof

Galileo Galilei (gal-uh-LAY-oh gal-uh-LAY-ee), born in Pisa, Italy, in 1564, helped change many of the ideas that people had believed for a long time.

Today, Galileo is remembered as one of the first scientists to seek proof for his ideas. He did not believe in accepting something as true just because Aristotle had said it was true.





What are the scientists doing in these two pictures? What ways of making comparisons are shown? Why is it important for scientists to keep accurate records of their work?

Galileo was an observing man, and he asked many questions about what he observed. Sometimes what he observed did not agree with what Aristotle had said was true. Then Galileo set about finding proof.

To find the answers to his questions, Galileo measured, weighed, and timed things. He believed in trying not once or twice, but many times, until there could be no doubt about his answers. He compared what actually happened in his experiments with what he thought might happen. For example, he figured out where a cannon ball would land when fired from the mouth of a cannon. After the cannon ball landed, Galileo checked his figures.

Galileo questioned the scientific ideas he heard and read about. He was always asking "how" questions. Most of the time, the only answers

Galileo got to his questions were, "This is the way it has always been done," and "It is not for you to ask *how*."

Answers such as these made Galileo want to find out all the more. One of the things he was most interested in was *how* things fall to the earth. Aristotle also had been interested in falling objects, but Aristotle had only asked *why* things fall to the earth.

Galileo believed that anyone who asked *why* things fall to the earth got the wrong answers. He got "because" answers, like Aristotle's. Aristotle had said that things fall to the earth *because* they are heavy. They go toward their natural place, which is the earth, said Aristotle, *because* the earth is the heaviest of all things. Heavy things fall faster than light things *because* they have more power to seek the earth.

But suppose you ask, as Galileo did, "*How* do things fall to the earth?" If you are going to find out *how,* then you must ask:

How far does the thing fall?
How long does it take to fall?
Does it speed up as it falls?

If you want to know whether heavy things fall faster than light things, there is one more question to ask. What is the question?

To find answers to his questions, Galileo measured things. Then, using his measurements, he tried to guess what results he would get if he did certain experiments.

The Swinging Lamp

A story is told that one day, while in the cathedral of Pisa, Galileo watched some workmen busily making repairs to the roof. Their hammering caused a lamp hanging from the ceiling to swing back and forth. Suddenly, Galileo found himself watching the lamp. As he watched, he asked himself such questions as:

1. Does each swing of the lamp take the same amount of time?
2. Does the lamp swing as high to one side as it does to the other side?
3. Suppose the chain holding the lamp were shortened or lengthened. Would that make any difference in the time it would take the lamp to swing back and forth?
4. Suppose a heavier or lighter lamp were used. Would that make any difference in the time it would take the lamp to swing back and forth?

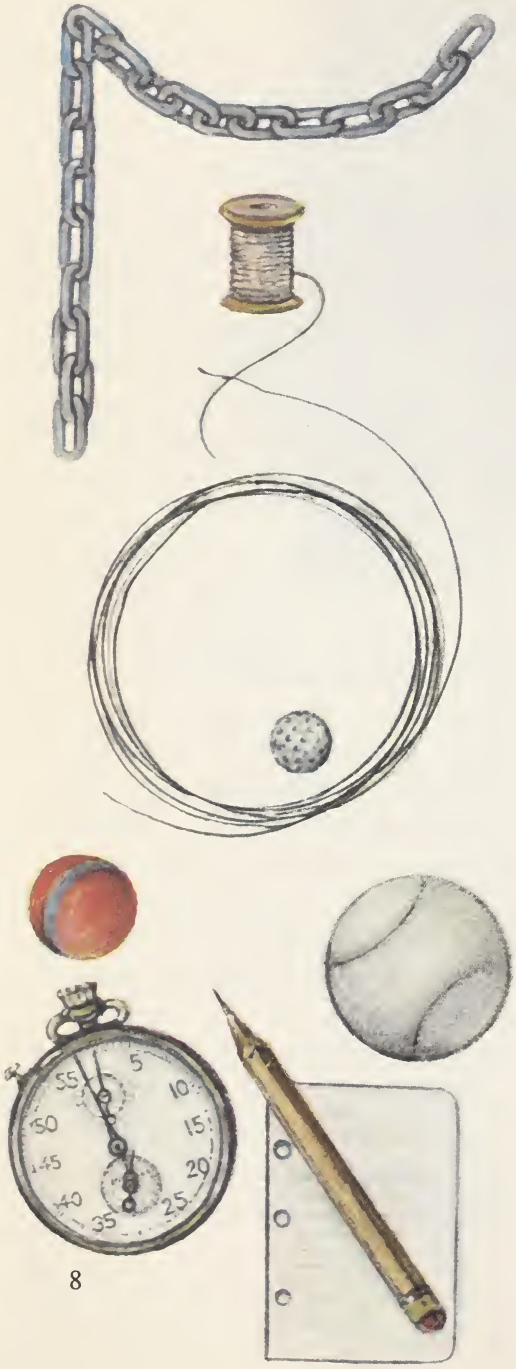
Have you ever seen something happen and then wondered how it happened? Did you try to find out how it happened? What steps did you follow to find out?

Puzzled, Galileo went home thinking about how he would find the answers. He spent days finding the materials that he needed. He collected strings, wires, chains, and iron and wooden balls of the same size but of different weights. He also needed an hourglass, his quill pen, ink, and paper. Do you know why the last four things are just as important as the other things?

Now he was ready. He tried out the strings, wires, and chains of different lengths with balls of different weights. At times, he had to try out long lengths of string and wire. To do so, he climbed a tree and hung the weights from the tree.

Galileo Finds the Answers

After many experiments, Galileo found the answers to his questions. Although he did not realize it at the time, Galileo was helping to develop the ways of science that are used by today's scientists. Can you tell how he helped to develop these ways?



Galileo's experiments proved that Aristotle's ideas about swinging objects were wrong. Anybody can do the same experiments that Galileo did. If he does them carefully, he will find the same answers Galileo found.

You can find out what Galileo found out about swinging objects. Look again at the questions Galileo asked himself and plan experiments to find the answers. You can find the questions on page 6. Here is a list of the materials you will need:

Strings, wires, or chains of different lengths (2 of each).

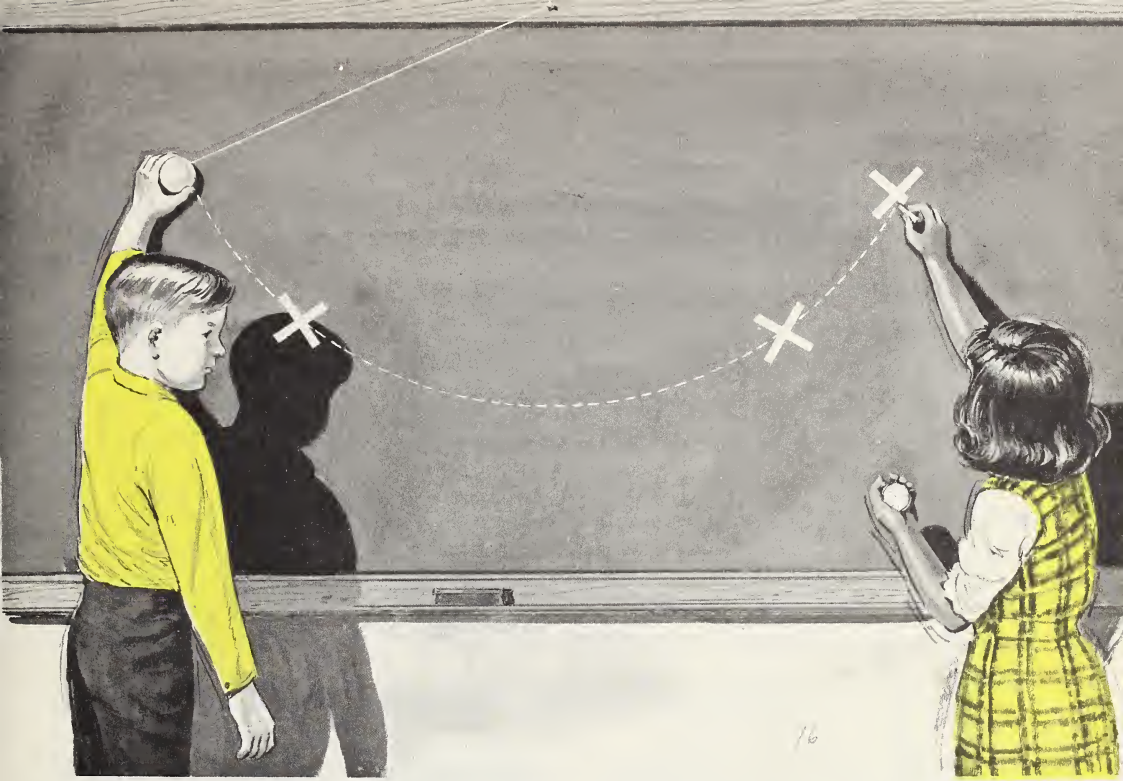
Balls of different weights, such as rubber balls, golf balls, or baseballs (2 of each).

A watch with a second hand.

Pen or pencil and some paper.

Think about the questions Galileo asked himself. You can find the answers to these questions by doing the following things:

1. Attach strings, wires, or chains of different lengths to balls of different weights.
2. Hang the balls so that they can swing freely—that is, without hitting anything.



The ball makes a curve, or *arc*, as it swings back and forth. How are the children in the picture measuring the distance from one end of the arc to the other end?

3. Raise each of the balls, keeping its string taut. Then release the ball. Measure the distance from one end of the arc to the other. Here is a suggestion: Let each ball swing in front of the chalkboard. When the highest position for each swing is reached, mark that point on the chalkboard. See how this is done in the picture.

4. Use a watch with a second hand to time each of ten swings. If you find it difficult to time the swings and count them at the same time, have a classmate time each swing while you count the swings.

What did Galileo measure to find the answers to each of his first three questions? What did he compare?

Checking Your Results with Galileo's

You have now done the same kind of experiments as Galileo. Did you get the same results? Galileo found that:

1. Each swing of a ball took the same time no matter how wide or narrow the arc. When the arc was wide, the ball swung more quickly. When the arc was smaller, the ball moved more slowly. But the time it took to complete a swing was always the same.
2. Each ball swung as far to one side of the center of its swing as to the other. Each ball swung as high to one side as to the other side.
3. The time it took for the ball to swing from one end of its arc to the other depended only on the length of the string.
4. No matter what the weights of the balls, if the strings were the same length, the balls swung from one end of their arcs to the other in the same time.

Did you get the same answers as Galileo did? Aristotle had said that it would take less time for the weight to make a complete swing if the arc were small. But Galileo's experiments proved Aristotle's idea was wrong.

Many hundreds of scientists have done these experiments and proved Galileo to be right. And even though you are not a scientist, you, too, can prove Galileo to be right. Galileo's way — measuring, weighing, timing, testing, and keeping accurate records — has become the way of all scientists.

Reviewing Galileo's Experiment

In doing each part of Galileo's experiment, you compared what happened in one test with what happened in

This scientist is using the ways that all scientists use — the ways that Galileo used.

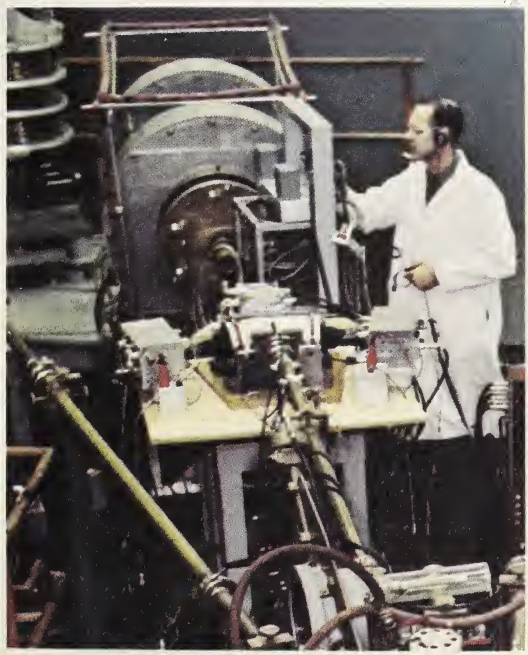
another. The things that you kept the same are called **controls.** Why do you need controls? What controls did you use to answer the questions in Galileo's experiment?

Let's go back to the first part of Galileo's experiment, where he asked, "Does each swing of the lamp last the same amount of time?" He thought that time might change. To check on *time,* he kept the weight of the ball and the length of string the same. Can you tell why he did his experiment this way? What would have happened if he had changed the weight of the ball? In doing an experiment, you test for only *one* thing at a time.

What did you keep the same to find the answer to Galileo's last question, "If a heavier or lighter lamp were used, would that make any difference in the time it would take the lamp to swing back and forth?" What was the one thing you were testing for?

What one thing was different in your experiment? The thing that is different is called the **experimental factor.** There should never be more than one experimental factor in an experiment. Can you tell why?

In the two pictures below, scientists are testing things. Can you tell how they are testing? Look again at the scientist on page 10. What do you think he is doing?



By doing the same kind of experiments that Galileo did, you have used some of the ways of the scientist—measuring, weighing, timing, testing, and keeping accurate records.

You will do many experiments as you find out more about the world in which you live.

Things to Remember

Now let us review some of the important things to keep in mind whenever you do an experiment:

1. Plan your experiment carefully. Make certain that you will have all the materials you need.
2. Be sure you know what questions you want answered. Make a list of the questions. What questions about the swinging lamp did Galileo ask?
3. Know what you must observe to get the answers. What did Galileo observe to get his answers?
4. Be sure you have a way to observe. How did Galileo observe the different swinging balls?
5. Keep an accurate record of everything you observe. Then study your records. Why is it important to study records?

PATHFINDERS IN SCIENCE

Aristotle

(384 B.C.–322 B.C.) Greece

"It is the business of wisdom to discover the causes of visible things."

This thought was written by Aristotle, the Greek scientist and philosopher. It guided him throughout his life.

Aristotle studied a problem by first breaking it down into its smaller parts. Then, having studied the smaller parts, he would try to see how and why the parts fit together.

Before Aristotle, scientific ideas were based on guesses. Aristotle believed that the truth could be found only by observing. He also believed it was important to keep records of what he observed.

There are many ways to observe things. For example, a person might simply watch as a bee sucks nectar from a plant. But Aristotle would do more than just watch what was happening. He would take the bee and the plant home and look inside them to see why and how they were the way they were.

If Aristotle wanted to study the breeding of catfish, he would spend days by the sea watching them. Then he would take one home and cut it open to see what was inside it. His work took many

years, and he collected many, many notes. In fact, he kept records of the habits, breeding, and structure of 455 different animals.

Aristotle was also a thorough researcher. He not only studied the work of those who came before him, he also listened to hunters, fishermen, and farmers who knew much about plants and animals. Every fact was important to Aristotle. He believed and taught that everything that can be observed in each of the sciences is important and must be carefully studied.

When we think of today's scientists at work, we think of microscopes, telescopes, test tubes, and other instruments. Two thousand years ago, when Aristotle tried to learn more about the world in which he lived, there were no such scientific instruments. But even without these instruments he studied almost every known branch of science.

Aristotle's brilliant mind and his ability to teach enabled him to bring together in one place all the knowledge of his time. His own studies and discoveries added much to that knowledge.

Aristotle's ideas about the things he studied were to help men for centuries to come—even to this day. We know now that many of Aristotle's ideas were not correct. But his studies prepared the way for men to find the truth. They served as steppingstones to new discoveries. His lasting contribution to the world was to give scientists knowledge and experience to build upon.

Aristotle was one of the world's greatest thinkers. He studied almost every field of science. His ideas have helped other scientists for over 2,000 years.

Using What You Have Learned

1. Here are five questions. How would you go about finding the answers to these questions? Do you need to do experiments to answer these questions? Do you need to make comparisons to find the answers to these questions? If so, tell what you are comparing.

   a. Do hamsters like raw vegetables better than cooked vegetables?
   b. Does plant food make potted plants grow better?
   c. Do things weigh less when they are in water or when they are in air?
   d. Does it take less time to bake a potato when it is wrapped in aluminum foil or when it is not?
   e. Which city is farther from your home—New York or San Francisco?

   Would you have to measure anything to get the answers to the questions above? What would you measure? Would you have to time anything? What would you time?

2. Do you always need to do an experiment to find the answer to a question? For example, do you need to do an experiment to find out who is the tallest boy in your school? Can you do an experiment to answer the question, "Is it wrong to steal?"

3. What color is best for the wall of your classroom? Brown? White? Green? Yellow? Which do *you* like best? Which one gives you the most light? You will need a light meter for this experiment. Light meters measure the amount of light. They are used in taking photographs. Perhaps you can borrow one from a friend.

Place papers of different colors inside the box. Use a light meter each time and record the number shown on it. How does the number change when you change papers?

Get a box like the one in the picture and cover the inside with paper of one color. Put an electric lamp in front of the box. Hold the light meter at the other side so that only the light reflected from the colored paper hits it. The more light the paper reflects, the higher the number shown on the meter will be. Now try paper of some other color. Read the meter again. Compare the different colors of paper that you have selected. What did you find out?

4. What color clothing should boys and girls wear to be seen most easily when riding bicycles at night? How would you go about answering this question?

WHAT YOU KNOW ABOUT

The Scientist's Way

What You Have Learned

Scientists use **comparisons** to help them get the answers to many of the questions they have about the world around them. But scientists are not the only ones to make comparisons. You, too, use comparisons to learn about things. Sometimes scientists use **instruments** to make more accurate comparisons. You, too, use instruments. You must always measure and compare very carefully and accurately.

Galileo was one of the first scientists to answer his questions by doing **experiments.** In doing his experiments he used comparisons.

When you do an experiment, you should test for only one thing at a time. The things you keep the same are called **controls.** The one thing that is different is called the **experimental factor.** There can never be more than one experimental factor in an experiment at one time.

When you do an experiment, plan it carefully so that you find out what causes the changes you observe. Be sure you know what you want to find out. Make a list of the questions you want answered. Know what you must observe. Keep an accurate record of everything you observe.

Checklist of Science Words

Here are some science words you read about in this unit. Can you tell what you have learned about each one?

comparison	experiment	instruments
controls	experimental factor	

Complete the Sentence

Write the numbers 1 to 5 in your notebook. Next to each number, write the answer that best completes the sentence below.

1. Scientists use special tools called _____?_____ to help them compare things more exactly.
2. The one thing that is different in an experiment is called the _____?_____ _____?_____.
3. The things you keep the same in an experiment are called the _____?_____.
4. Three ways that the scientist uses to compare things are _____?_____, _____?_____, _____?_____.
5. _____?_____ was a scientist who questioned the teachings of Aristotle.

True or False?

In each sentence below, one or more words are underlined. These words make the sentences true or false. Write the numbers from 1 to 5 in your notebook. If the sentence is correct, write "true" next to the number in your notebook. If it is false, write in your notebook the word that will make the sentence true.

1. In an experiment, the one thing that changes is the experimental factor.
2. You cannot find all the answers by experimenting.
3. Aristotle is known as the first of the modern scientists.
4. Observing, timing, and weighing are three of the ways of the scientist.
5. You should never have more than two experimental factors in an experiment.

YOU CAN LEARN MORE ABOUT

The Scientist's Way

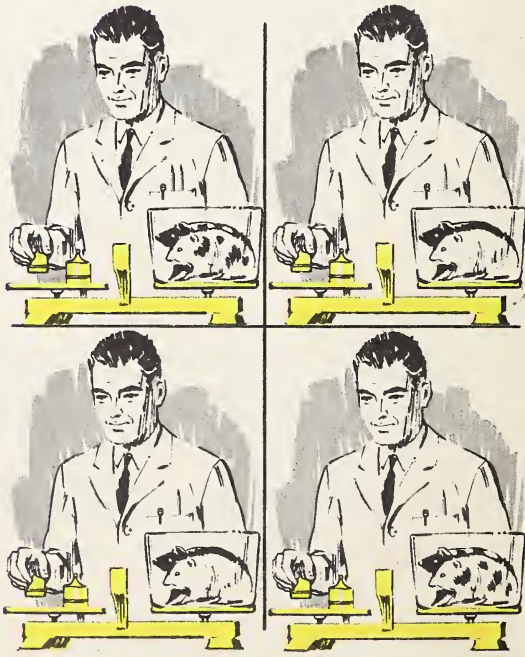
Unscramble the Letters

1. The things you keep the same in an experiment.
2. The special tools of the scientist.
3. Finding out what is different and what is alike about things.
4. One of the first scientists to do experiments.
5. The one thing you change in an experiment.
6. The distance from one end of a swing to the other.

1. NOLTROCS
2. STEMINNRUST
3. SCARPMOINO
4. ALIEGOL
5. MERILATXPEEN CAOFTR
6. RAC

Can You Tell?

Here are four pictures of the same scientist doing the same experiment—but are they really *exactly* the same? Look again. Compare the four pictures and see if you can find the two that are exactly the same.



Do You Know?

Before scientists sent a man into space, they had to do many experiments to make sure it was safe to do so. Read about some of the experiments that scientists and astronauts did in order to send a man into space.

Tell how making comparisons was important in these experiments. You might use these books to help you:

Space Monkey by Olive W. Burt
What Colonel Glenn Did All Day by Robert W. Hill

You Can Read

1. *Great Men of Science* by Arnold Dolin. The stories of many famous scientists.
2. *Tools of the Scientist* by Rhoda Goldstein. Many different scientific instruments are shown.
3. *They Wanted the Real Answers* by Amabel Williams-Ellis. You can find out more about Aristotle.
4. *What Does a Scientist Do?* by Harry Zarchy. An introduction to the world of scientists.
5. *The First Book of Science Experiments* by Rose Wyler. Do your own experiments at home.

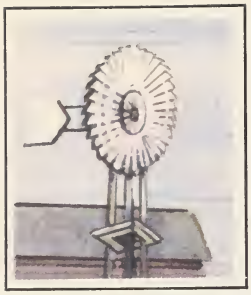
2

Understanding Energy

Using Energy

Using Simple Machines

What Stops Things That Are Moving?



Pick up your science book. You have just done some **work**! Did you require any **energy** to do this work? Yes, but not much. Energy is the ability to do work. You need much more energy when you go swimming than when you lift a book. But no matter what work you do, you use energy.

Using Energy

Look at the pictures below. See how the falling water turns the wheel. The falling water is doing work. There is energy in the falling water. Look at the next two pictures. Does the wind have energy to do work? Does the wood have energy to do work? What work is each doing?

Light is one form of energy. Electricity is another. Heat is another. And sound is still another. All these forms of energy can do work.

You use energy all the time. It takes energy to move any part of your body. For example, it takes energy to keep your heart beating. It takes

How can you tell if water, wind, and fire have energy to do work? Where does the energy come from? How many different forms of energy can you name?

Look very carefully at this picture. How many forms of energy do you see? How do these different forms of energy do work? Where do you think the energy comes from?

energy just to move your eyes back and forth across this page as you read.

But where do you get your energy from? You get your energy from the food you eat. All food actually has energy stored in it—energy that comes from sunlight. When you read about green plants, you will learn that energy from the sun is in the food you eat. You will also learn that all living things depend directly or indirectly on green plants for their energy.

You eat many foods. In the cells of your body, some of your food is "burned." When this happens, the energy stored in the food is set free. Your cells use this energy to do work. You can pick up things, play games, and do hundreds of things—all because food gives you the energy to do work.

Machines Use Energy to Do Work

Suppose you wanted to travel across the United States. Of course, you could walk about 3,000 miles across the country, but it would take too much energy for you to do that. It would be much easier to use the energy of machines. Machines make use of different kinds of energy. Machines can make use of mechanical energy, electrical energy, and heat energy.

We use electrical energy to run big machines, like printing presses and elevators, and to run small machines, like vacuum cleaners and washers. We use heat energy to cook our meals. Scientists use nuclear energy to run submarines. Do you know what else they use nuclear energy for?

Many kinds of energy are used daily to get things done—to do work. Make a list of all the work you did today in which you used energy that did not come from your own muscles.

Where Does Energy Come From?

Anything that can burn has energy stored within it. Coal, oil, and gas have energy stored within them. When they are heated, the energy is released.

What forms of energy are being used to run the printing press? What type of work is being done by the printing press?

What form of energy is being used to cook the food on this gas range? Where does this form of energy come from?

Most of the energy in our world comes from the sun. Without the sun there would be no food, coal, oil, or gas—our principal sources of energy.

Energy Can Change Its Form

One example of how energy can change its form is found in the automobile engine. When someone starts an automobile engine, gasoline begins to burn inside the engine. The burning gasoline creates heat. This heat, which is a form of energy, makes certain parts of the engine move. These moving parts of the engine make other parts of the car move. Scientists say that when an object moves, that object is using **mechanical energy.** Do you see how the energy inside an automobile engine is changed from heat energy to mechanical energy? You will learn later how other forms of energy can be changed.

This is an atomic submarine. From where does this submarine get its energy? From where does this form of energy come?

Energy Has Many Forms

Rub your hands together. You are now using the energy of motion, or mechanical energy. Keep rubbing. Are your hands getting warmer? You are changing mechanical energy into heat energy.

Here is another example of energy being changed from one form to another. Pump air into a bicycle tire. After you push the plunger down and pull it up a few times, feel the pump. Is it warm? Explain what happened.

Stored Energy

You have been reading about **energy in action.** There is another kind of energy. It is called **stored energy.** Stretch a rubber band. The stretched rubber band has stored energy within it. Let one end go. It snaps back and hits your finger. The stored energy becomes energy in action.

PATHFINDERS IN SCIENCE

James Prescott Joule

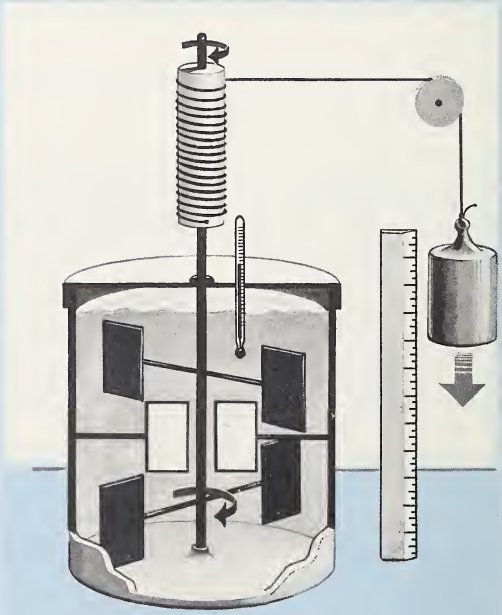
(1818–1889) England

We know that heat is a form of energy. But we didn't *always* know this. Someone had to find out.

At the end of the eighteenth century, scientists thought that heat was something taken in by an object when the object's temperature rose. When the object's temperature fell, the heat supposedly escaped into the atmosphere. Since the weight of an object is not changed by heating, scientists reasoned that heat was weightless. This explanation worked very well for materials that were heated over a flame, but it didn't really explain the heat given off by friction.

In the 1840's an amateur scientist, James Prescott Joule, set up an experiment in which a small paddle wheel kept

James Joule used the materials below to find out if a certain amount of mechanical energy always produces the same amount of heat.



turning in a certain amount of water. He was able to measure the amount of heat given off by the friction of the paddle wheel turning in the water. He also measured the amount of mechanical energy caused by the friction. Joule discovered that a certain amount of mechanical energy always produces the same amount of heat.

Next, he answered the question, "What does heat have to do with friction?" Joule found that a certain **amount of motion** (or **friction**) always turns into the **same amount of heat.** One kind of energy is simply changed into another. Every bit of mechanical energy given off becomes heat energy. This experiment showed that heat is another form of energy and *not* a "substance."

Joule's work led to one of the basic laws of science. His experiments showed that when one form of energy is changed into another, no new energy is created and no old energy is destroyed. One kind of energy is simply changed into another kind. In 1847, another scientist, Heinrich von Helmholtz, put these findings into words as the *Law of the Conservation of Energy.* This law says that energy can be changed from one form to another but cannot be created or destroyed.

Stored Energy to Energy in Action

A blown-up balloon has energy stored within it. Stick the balloon with a pin and the stored energy becomes energy in action.

Bob did not know about stored energy. Knowing about stored energy might have helped him. Before going away on vacation, Bob placed some blankets in a box on a very high shelf. Finding it hard to keep the cover closed on the box, he placed a large book on top of the box. When he came home from his vacation, he needed the blankets. He stretched up on his tiptoes and pulled the box down. But he forgot about the book. Down it came, hitting Bob on the forehead.

Bob found out that the book had energy stored in it. And this energy was released when the book fell. The book did work—although Bob was not very happy about the work it did.

Lift a weight. The weight now has stored energy. How did it get there? Drop the weight. What happens to the stored energy? The stored energy is changed into mechanical energy—the energy of motion. Energy can do useful work, but it can also cause accidents if you are not careful.

Setting Things in Motion

A moving object has energy. It can do work. But what starts an object moving? Bicycles, roller skates, wagons, toy cars, sleds, and swings do not start to move by themselves. Things stay where they are unless something starts them moving.

Could your book move by itself? What could happen to make it move? What things could you do to move it?

How would you move your chair? Would you move the teacher's desk in the same way? Would you move a heavy desk in the same way if the floor were covered with a thick rug?

It always takes something called **force** to set anything in motion. Force is the push or pull on an object. When you walk, run, skate, ride a bicycle, hammer nails, throw a ball, or turn the pages of this book, you are using force. Even if you push against a wall and it does not move, you are still using force. You just are not using enough force to move the wall. It takes more force to

How is the boy below using force? Is he doing any work? How can you tell?

move something heavy than to move something light.

Scientists say that work is done only when a force actually *moves* an object. When you push as hard as you can against a wall, are you doing any work? You might think so, but a scientist would say that you are not. Since the wall you push against does not move, you are not doing any work.

Why doesn't the wall move? The force you use is not great enough to move the wall.

Energy, force, and *work* are words that you have used for a long time. But now you are using them in new ways—the ways scientists use them. You have found that these words all have something to do with each other. Before reading on, can you tell how they are related to each other? Which of the three must always come first?

Here is an example of how energy, force, and work are related. You have *energy* in your muscles. When you use your muscles to throw or "push" a baseball, you are using *force.* Since the baseball moves through the air, you have done *work.*

Can you now explain how energy, force, and work are related in each of these groups of words:

1. Gasoline, snow plow, snow
2. Boy, rock, windowpane
3. Horse, corn and oats and hay, wagon
4. You, pencil, notes
5. Cat, milk, tree

Would you say that in each case the work done was *useful* work? Does work have to be *useful* to be work?

How is this boy using force? Is he doing any work? How can you be sure of your answer?

Using What You Have Learned

Here is a picture of a busy street. There are many kinds of machines and many kinds of energy being used. Look carefully and list in your notebook the different kinds of machines and the kinds of energy you find.

Can you tell where force is being used in the picture below? Can you tell how many different kinds of work are being done? Can you tell how energy, force, and work are related in the activities taking place in the picture?

How will the boy lift the rock? Is he using a machine? How would you lift it? How are energy, force, and work related in the activity?

Using Simple Machines

Suppose you want to move a heavy rock. You can move it the way the rock in the picture is being moved. You are using a machine to help you—an iron bar. You may not think of an iron bar as a machine, but it is one. The iron bar is really a simple machine called a **lever.**

Not all levers are iron bars, but levers generally work in the same way as the iron bar that you see in the picture. When a carpenter uses his hammer to pull a nail, the hammer is really a lever. When you use a shovel to dig, the shovel is a lever. When you use a shoehorn to put on your shoes, the shoehorn is a lever.

You can lift a heavy pile of books with a lever right in your classroom. A broom handle or stick can be a lever.

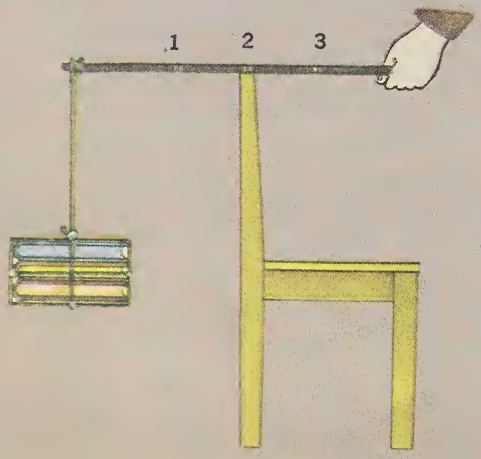
How Does a Lever Help to Move Things?

What You Will Need

broom handle or stick
long, heavy string
pencil or other marker
pile of books
chair

How You Can Find Out

1. Tie the books together with the string.
2. Then tie the string to the end of the broom handle or to the stick.
3. Make three marks on the stick, as you see in the picture.
4. Now put the stick over the back of the chair.
5. Try lifting the books three separate times with the stick resting at a different mark each time.



Questions to Think About

1. At which mark does it take the least force to lift the books?
2. At which mark does it take the greatest force to lift the books?
3. What does this tell you about one way to lift a heavy weight?

How Do Wheels Help Things Move?

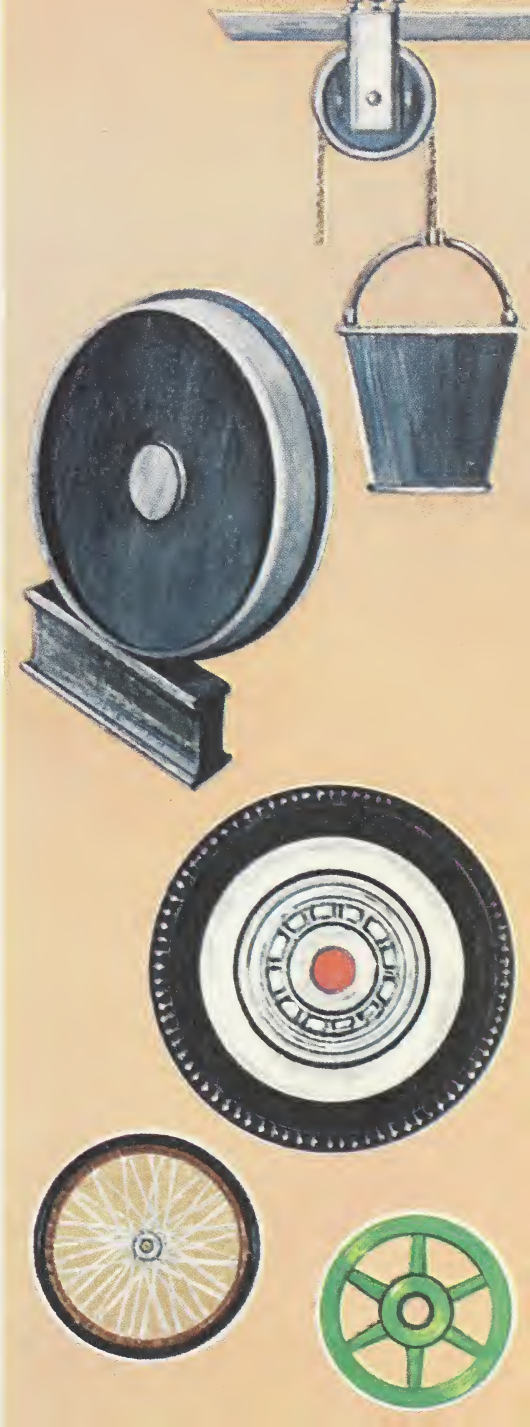
Many things are too heavy for people to move. But sometimes these things can be moved with the help of wheels. The pictures show some ways of using wheels to help move things. How are the wheels of each thing moved? The **pulley** in the picture is a simple machine. A pulley is used for lifting objects.

Sometimes wheels are moved by the force supplied by other wheels that are turning. This happens when you use an eggbeater, or when the little wheels turn inside a watch or a clock.

Wheels are moved by the force supplied by other wheels when you ride on your bicycle. The muscles of your legs supply the force that makes the sprocket wheels turn. When two sprocket wheels like those on a bicycle are joined by a chain, what happens when one of them is turned?

The experiment that begins on the next page will help you find out about sprocket wheels on a bicycle and how they work together. Do you know how a sprocket wheel got its name?

How are these different kinds of wheels used to move things? What kinds of wheels are they?



What Happens When a Bicycle's Sprocket Wheel Is Turned?

What You Will Need

bicycle watch with a second hand

How You Can Find Out

Part I

1. Turn a bicycle upside down and turn the pedals slowly with your hands.
2. What happens to the two sprocket wheels?
3. Does one move faster than the other?
4. What does the chain do?
5. What would happen if the chain broke?

Part II

1. Stop turning the pedals, but do not put on the brake.
2. Do the sprocket wheels stop turning right away?
3. Turn the pedals faster. What happens?
4. Stop turning the pedals. Does the back wheel stop as quickly now as it did when you turned the pedals slowly?

Part III

1. Turn the pedals slowly for 15 turns.
2. Measure the time it takes the wheel to stop. (Two or three timekeepers would be better than one.)
3. Now turn the pedals fast for 15 turns.
4. Measure the time it takes the wheels to stop.
5. What does this tell you about stopping a bicycle when you are riding it?
6. Count the sprockets on the front sprocket wheel. Then count the sprockets on the rear sprocket wheel. What does this tell you about how the two sprocket wheels are related?

This picture is a closeup view of the sprocket wheels of the bicycle.

Questions to Think About

1. Watch the two sprocket wheels on the bicycle when the wheel is turning. Can you tell why one is made smaller than the other?
2. Suppose the two sprocket wheels were changed so that the small one was near the pedals. Would the wheel go faster or slower if you turned the pedals?
3. The front wheel of the bicycle does not turn when the pedals are turned. What makes it turn when you ride?
4. Why is the rear tire of a bicycle likely to wear out before the front tire? Can you think of two or three reasons?
5. When you ride a bicycle, how are energy, force, and work related?

How Do Steam and Other Gases Make Things Move?

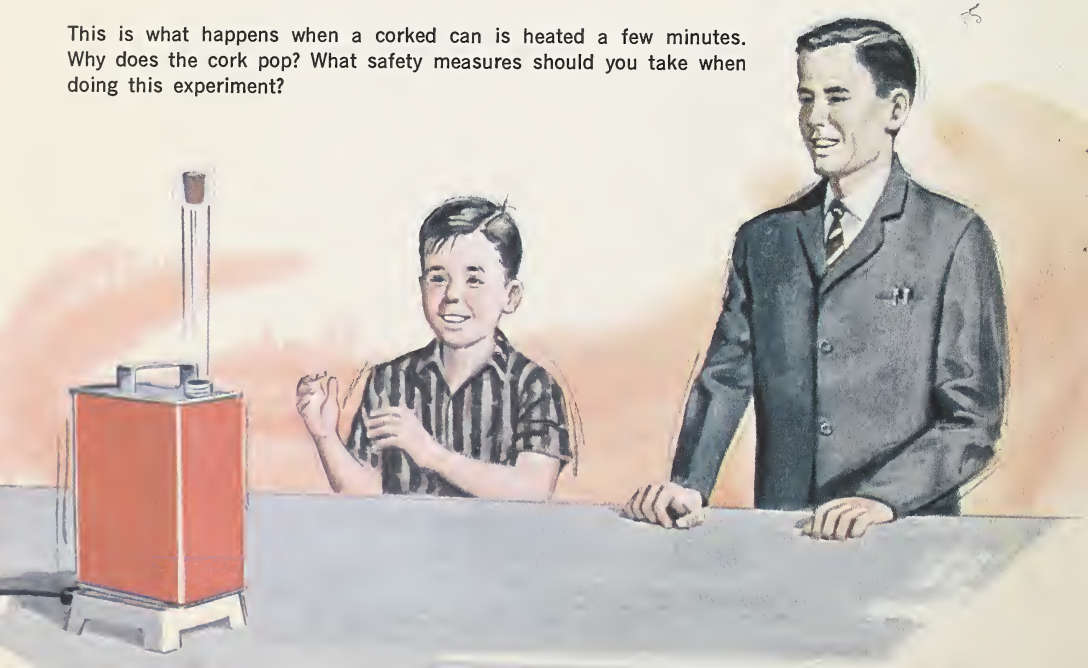
Some wheels are moved by the force that our muscles produce. The wheels on your bicycle and on a wagon are moved this way. But many wheels are moved by another force—the force of a gas. In Tom Peterson's class, the teacher and students tried to see how this happens.

Tom put a cork in an empty can like the one in the picture. His teacher heated the can for a few minutes. What happened to the cork? As the air inside the can got hotter, the air took up more space. Since there was not enough room for the air in the can, the air pushed harder against the cork and the sides of the can. The air pushed so hard that it blew the cork out of the can. What would happen if you pumped air *out* of the corked can?

Do you know what sometimes happens to the lid of a pot when the water boils inside the pot? The lid bounces up and down. Do you know why? When you boil water, the water turns to steam. Since steam takes up more room than water, it pushes upward on the lid. The steam pushes with so much force that it raises the lid.

The force produced by large amounts of steam is used to turn the wheels of big machines. Can you think of other ways in which steam is used to move things?

This is what happens when a corked can is heated a few minutes. Why does the cork pop? What safety measures should you take when doing this experiment?



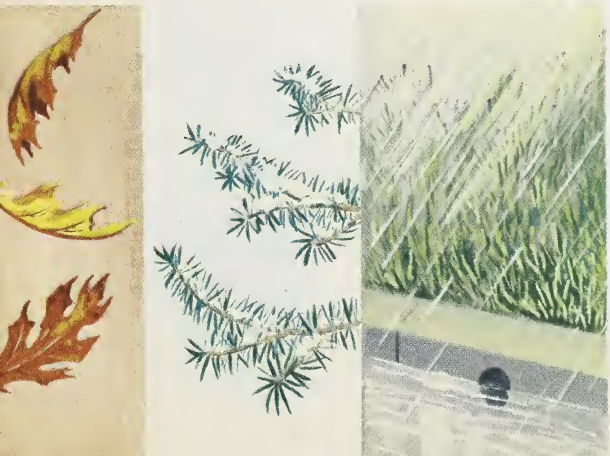
What force makes this boy slide down the hill?

How do you know the boy will hit the ground?

When gasoline burns, it changes to a gas very quickly. The stored-up energy is then released as heated gas. It pushes with great force against anything in its way. The force that is made by releasing this energy is used to turn the wheels of cars. It is also used to turn the propellers of airplanes. Can you tell about other things?

How Gravity Makes Things Move

There is still another force that makes things move. Hold a pencil in front of you. What happens if you let go? The force that makes the pencil fall is called **gravity**. It is the gravity of the earth that makes things fall to the ground unless there is something to hold them up.



What does the force of gravity have to do with each of these pictures?

EXPERIMENT

How Can You Measure the Force of Gravity?

What You Will Need

old inner tube
chalk or other marker
stones, sand, bits of paper, or anything you wish to weigh
toy pail
water
heavy string

How You Can Find Out

1. Cut a long strip of rubber from an old inner tube. It should be about three feet long.
2. Tie a toy pail to one end with heavy string.
3. Tie a loop of string to the other end and hang it from the wall or from a coat hook.
4. Use a piece of chalk to make a mark on the wall next to the bottom of the rubber strip.
5. Now fill the pail with water.
6. Make another mark on the wall to show how far the rubber stretched.
7. Try this with different things, such as stones, sand, bits of scrap paper, cotton, and sawdust.
8. Mark how far each one makes the rubber stretch.

Questions to Think About

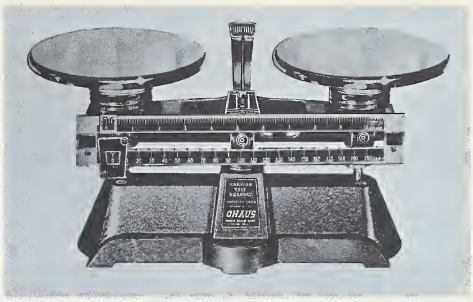
1. Which one was pulled toward the earth with the greatest force?
2. Which one was pulled toward the earth with the smallest force?
3. How have you measured the force of gravity?

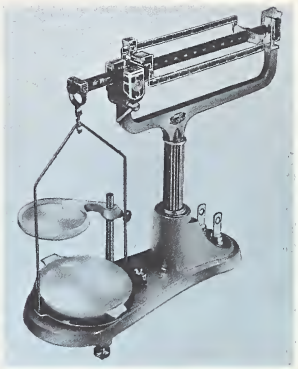
If there were no force of gravity, things would not weigh anything. When we say that a girl weighs 70 pounds, we mean that the earth's gravity is pulling her towards the earth with a force of 70 pounds. A 5-pound bag of sugar is pulled toward the earth with a force of 5 pounds. A pound of candy is pulled toward the earth with a force of 1 pound.

Here are some interesting questions about gravity for you to think about.

1. What force of gravity is pulling your body toward the earth?
2. Sometimes birds high in the air seem to float without moving their wings. Why doesn't the force of gravity pull these birds to the earth?
3. If it were not for the force of gravity, what would happen at a ball game when a batter hit a high fly?

On page 38 you learned one of the ways to measure the force of gravity. Scientists have instruments that can measure gravity more accurately. Do you know the names of any of these instruments? How are the two scales in the pictures different from each other?





When Things Fall from High Places

Which would be more likely to hurt you—a fall from the bottom step of a ladder or a fall from the top step? Which would hit the ground harder—an apple falling from the top of a tree or an apple falling from your hand?

You can show what happens to things falling from high places by measuring how deep they sink into mud. The experiment on the next page will help you.

These scientists are using an instrument called a *gravimeter* to measure the force of gravity.

EXPERIMENT

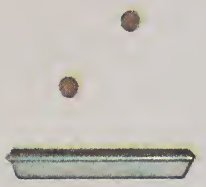
How Does Height Affect the Force of a Falling Object?

What You Will Need

shallow pan	ruler or tape	mud
marble	measure	ladder

How You Can Find Out

1. Fill a pan with mud.
2. Make the mud just soft enough so that a marble will leave a hole in it.
3. Drop a marble into the mud from a place three feet high. Measure how deep a hole it leaves.
4. Now drop the same marble from a place six feet high. Measure how deep the hole is.



Questions to Think About

1. Are both holes the same size?
2. Which is deeper? What does this show?

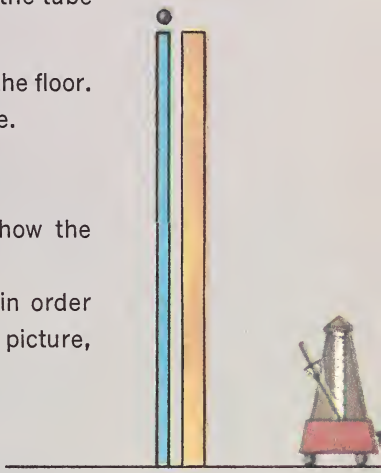
This experiment shows you that the farther something falls, the harder it will hit. It hits with more force because it is going faster. The farther it falls, the faster it goes.

Gravity is a force. Like other forces, it speeds things up as long as it acts. The longer you pump on a swing, the faster it will go. Pumping supplies the force. Even if the pumps

How Much Do Things Speed Up As They Fall?

What You Will Need

long, narrow tube of polyvinyl (3 feet, if possible)
marble
heavy-weight oil to fill the tube
metronome
strip of cardboard as long as the tube



How You Can Find Out

1. Fill the tube with oil, and hang it with its base touching the floor.
2. Stand the cardboard upright along the side of the tube.
3. Start the metronome.
4. At the first tick, drop the marble in the oil.
5. With each tick, make a mark on the cardboard to show the position of the marble.
6. Cut the cardboard at each mark, and paste the pieces in order on heavier cardboard. This will give you a graph, or picture, of how the marble speeded up. Label your graph.

Questions to Think About

1. How far did the marble fall between the first tick and the second tick?
2. How far did the marble fall during each time period after that?
3. During which time period did it fall the farthest?

are the same size, you will swing faster, so long as you keep on pumping.

The force of gravity is acting all the time on earthbound objects. For example, when an apple falls from a branch, gravity pulls the apple to the ground. Its constant pull speeds up the apple as it falls. The farther the apple has to fall, the more it speeds up. You can see this happening.

EXPERIMENT

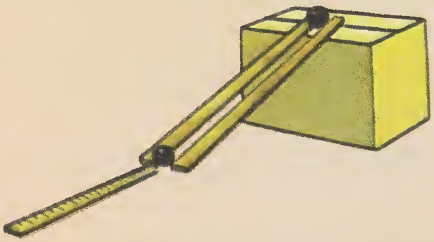
Do Things Hit Harder If They Fall Faster?

What You Will Need

marbles two yardsticks ruler or tape measure

How You Can Find Out

1. Roll a marble down a slope.
2. Use two yardsticks to keep the marble rolling straight down the slope.
3. Let it hit another marble at the bottom of the slope. Measure how far that bottom marble moved.
4. Make the slope steeper. Roll a second marble down the slope. Measure how far the bottom marble moved.



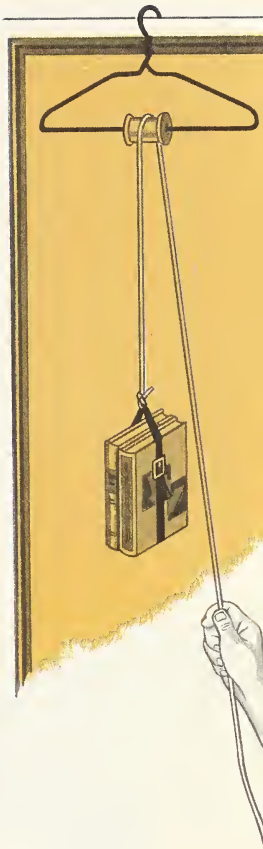
Questions to Think About

1. What happens to the bottom marble when the slope is steeper? Is it moved farther?
2. Try several different slopes. What happens each time?

What do the experiments so far tell you about what happens when you bump into a fence while running for a ball? Would you hit against the fence as hard if you were walking?

Why is there danger in going too fast on bicycles, roller skates, wagons, sleds, or other moving things? Why is there danger to yourself and to others if you run in the school halls?

Using What You Have Learned



1. With a pulley you can lift things *up* by pulling *down*. If you don't have a pulley, use an empty thread spool and a coat hanger wire to make a pulley. Hang your pulley in the center of an open door. Run a string over the pulley so that the ends of the string nearly touch the floor. The picture shows how the pulley should look. You can now lift up different things by pulling down on the string.

2. With a string, tie a book to one end of a long, heavy rubber band. Tie the other end of the rubber band to a coat hook or something else that sticks out from the wall. When the book stops bouncing up and down, measure how far it hangs from the coat hook.

   Now lift the book until it no longer stretches the rubber band at all. Then let go. Notice how far it stretches the rubber band on the first bounce.

   Why does the book stretch the rubber band farther than it did when it was just hanging?

3. You can show how rollers make things easier to move. Get a box about the size of a chalk box. Put stones or other heavy things inside it. Put the box on the floor and fasten a rubber band to one end of it. Hold a ruler beside the band and pull on the band until the box just begins to move.

   How long was the band stretched when the box started to move?

   Now put two round pencils under the box and pull on the rubber band. How long was the band stretched this time when the box started to move?

What Stops Things That Are Moving?

You know that nothing will move unless some force makes it move. In the same way, nothing will stop unless some force makes it stop. Someone on roller skates will keep moving for a while after he has been pushed. A bicycle wheel will keep moving for some time after you have stopped turning the pedals.

It is not very easy to stop roller skating when you are moving very fast. Can you tell why?

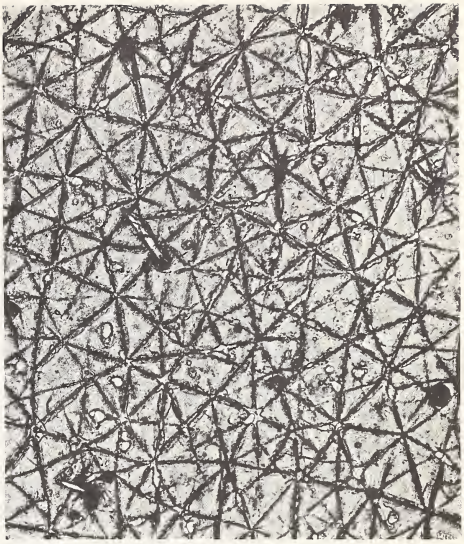
Just as you must apply force to make things move, you must apply force to make things stop. You remember that to make an object move, you had to apply force in the direction you wanted the object to move. But to make an object stop, you apply force in the direction opposite to its motion. The size of force you apply must be larger than the force that is acting on the object.

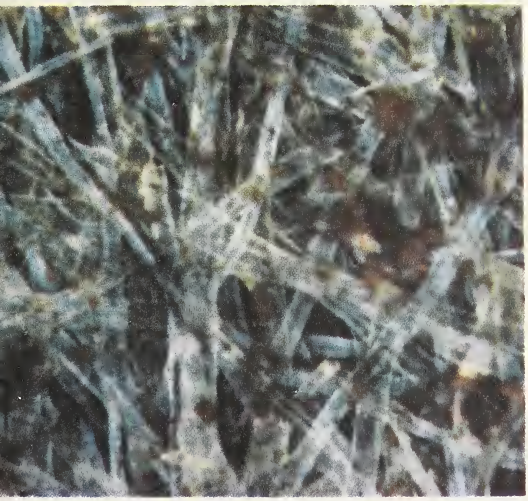
A car will coast for a time by itself, but after a time it will slow down and stop. In the same way, a boy on roller skates cannot coast forever. The car and the boy on roller skates stop because there is a force opposing their motion, even though you cannot see it. This force is called **friction** (FRIK-shun). Friction is created whenever two things rub against each other. For example, there is friction when your bicycle tires roll over the roadway. There is friction when ice skates glide over the ice. There is friction when a boat moves through the water. Even when you simply rub your hand lightly over the top of your school desk, friction is created.

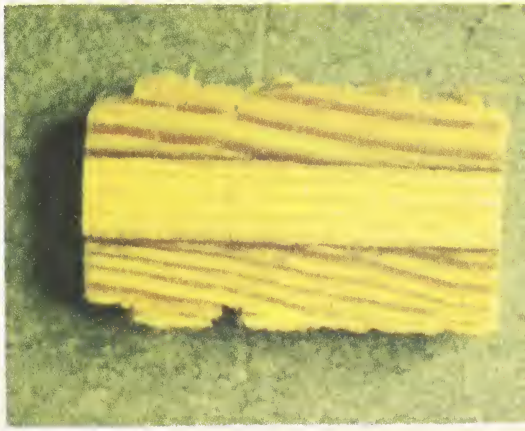
How Does Friction Stop Things?

Nothing is ever perfectly smooth, even though some things look smooth. Every surface has little bumps and hollows on it. If you look through a magnifying glass at something that is smooth, such as your skin or a page from a book, you will see that it is not as smooth as you thought it was.

These little bumps and hollows act as a force which can slow down and stop a moving thing. The little bumps and hollows on one object rub and catch against the bumps and hollows of







Look at all three pictures. Can you tell which is skin, which is paper, and which is wood? How are their surfaces different from one another?

Ice skates glide smoothly over the ice. Can you tell why they are able to do so?

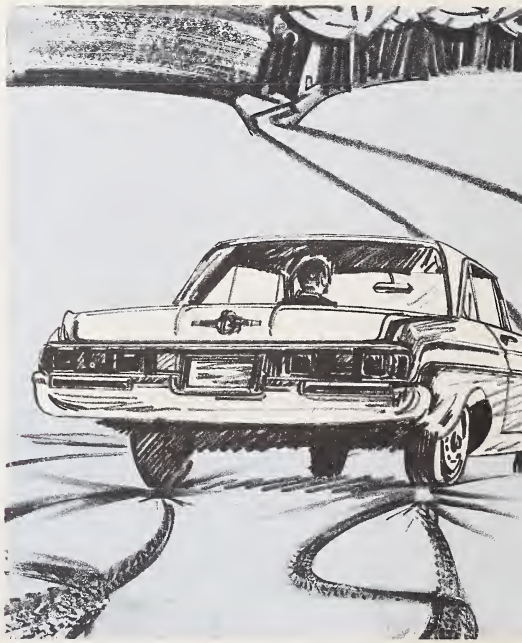
another object. This slows down the motion of the moving object.

If the two objects have many bumps and hollows in them, there is a great deal of friction. When two very smooth objects move against each other, there is not much friction. That is why ice skates slide easily on ice. For the same reason, a car or a bicycle skids on ice and keeps on moving longer than it would move on a dry road.

When we want to make objects move more quickly, we can use what we know about friction. Can you tell why cars go faster on smooth highways than on rough roads? Can you explain why railroad trains run on steel tracks? Can you tell why children's playground slides are so smooth?

You can find out what happens when there is very little friction. The next experiment will help you find out.

What safety measures must be taken when it becomes necessary to drive on icy roads?



What Happens When There Is Very Little Friction?

What You Will Need

small square of wood (about ½" thick)	glue	spool
	sandpaper	wax
	balloon	

How You Can Find Out

1. Make a small hole through the center of a small square of wood about half an inch thick.
2. Glue a small spool over the hole.
3. Sand and wax the bottom of the wood.
4. Blow up a balloon and stretch it over the spool. Keep your finger over the hole in the bottom of the wood so that no air comes out.
5. Take your finger away as you put the wood on a smooth surface such as a clean window pane.

Questions to Think About

1. Give the wood a push. What happens?
2. Can you explain what happened?

Scientists have shown that once a thing is moving, it will keep on moving until it is stopped by something. Why does the piece of wood in the experiment finally stop?

Have you ever heard of a "runaway" car on a railroad track? How far will it go before it stops? What stops it?

Do you know how the brakes on an automobile work? Is the automobile stopped by friction?

We can use what we know about friction to travel more safely. The next experiment will show you how.

EXPERIMENT

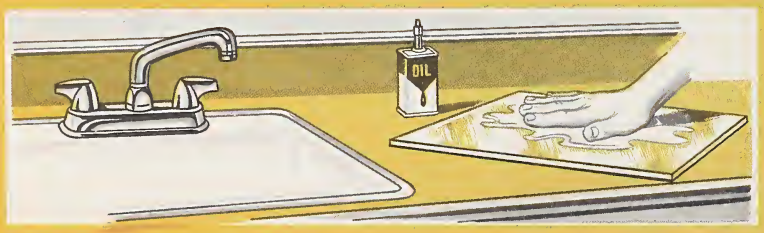
How Will Knowing About Friction Help You Travel More Safely?

What You Will Need

water piece of glass oil

How You Can Find Out

1. Rub your hand over a piece of glass.
2. Pour a little water on the glass.
3. Rub your hand over the glass again. Does your hand move more easily?
4. Dry the glass and pour a little oil on it.
5. Rub your hand over the glass again. What happens?



Questions to Think About

1. What does this tell about riding over wet or oily roads?
2. What do you think would happen if you tried to stop a bicycle or a car suddenly on a wet or oily road?

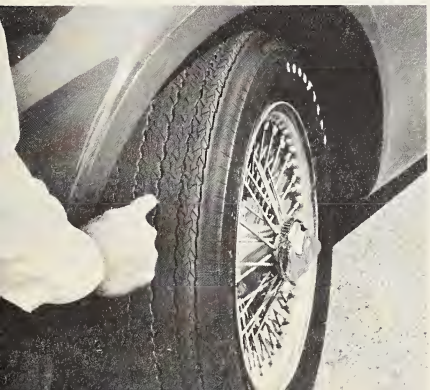
Look at a bicycle or car tire. Notice the grooves in the rubber. Can you tell why the tires are made this way?

Tires will skid on icy, wet, or oily roads. Old, smooth tires will skid more easily than new ones. Can you tell how tire chains help to keep a car from skidding?

Highway workers spread sand on icy roads because sand makes the roads rough. This roughness makes more friction, and cars can stop more easily.

Can you think of some ways to prevent accidents while riding a bicycle, while driving a car, or while walking on a slippery road?

What does each of these pictures have to do with what you now know about friction?



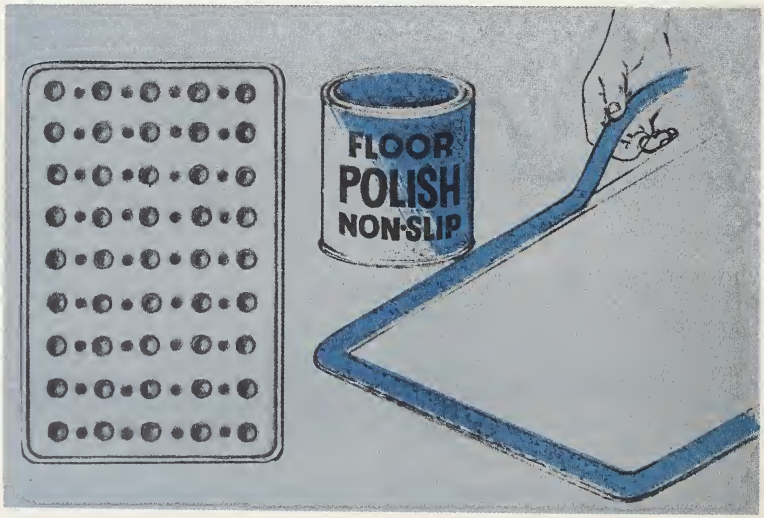
Using What You Have Learned

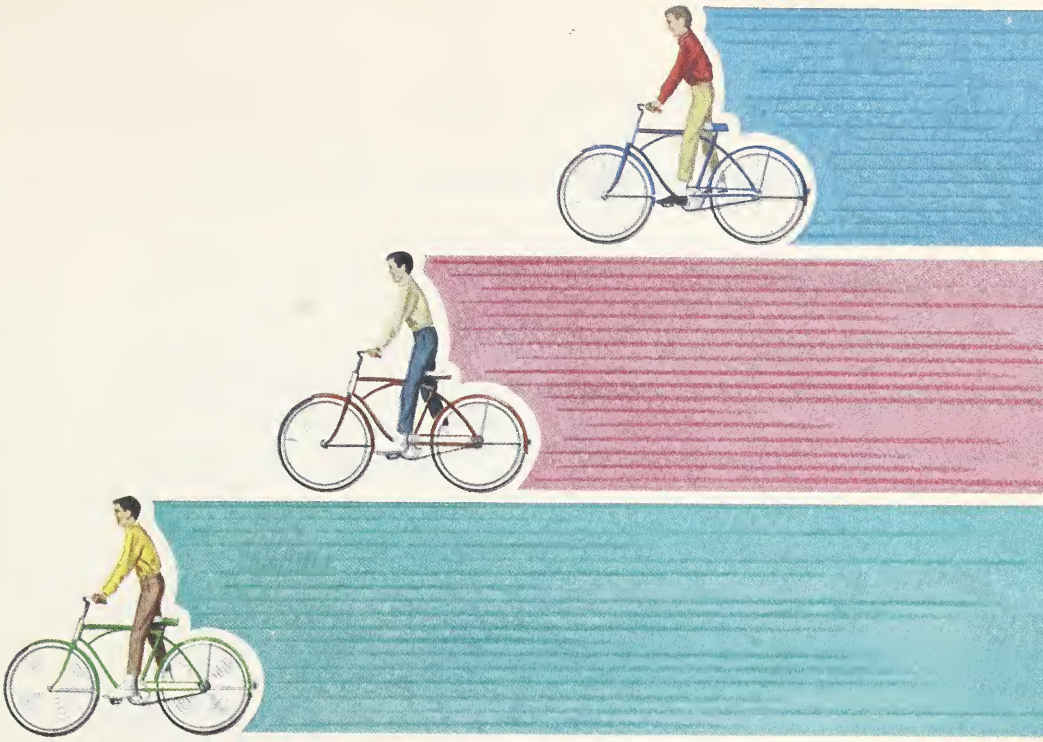
1. Which of these four would move in the same direction for the longest time, after the first push? Why?

   A sled with steel runners on ice.
   A sled with steel runners on fresh snow.
   A sled with wooden runners on ice.
   A sled with wooden runners on fresh snow.

2. Many accidents in the home are caused by sliding or slipping. These can be prevented if you think about the way friction keeps things from sliding. How could you use friction to keep the following accidents from happening?

   Slipping in the shower or bathtub.
   Falling on slippery floors.
   Falling when rugs slip.





3. Have a bicycle "rodeo" in your schoolyard to show safe bicycle riding. At one school's bicycle rodeo, three boys tried to find out how fast they could stop their bicycles. The boys found out that the faster they went, the more time it took them to stop. Try this at your rodeo. Measure how long it takes to stop when you are going at 5 miles per hour, at 10 miles per hour, and at 15 miles per hour.

4. Using what you have learned, make up a set of rules for safe bicycle riding. You may also want to have a bicycle "checkup." Everyone who owns a bicycle might check to see if all the parts are working properly. Be sure to check brakes, front lights and taillights, and horn.

WHAT YOU KNOW ABOUT

Understanding Energy

What You Have Learned

Energy is the ability to do **work.** There are many kinds of energy. **Light, electricity, sound,** and **heat** are four kinds of energy. All energy can be traced back to the sun.

Energy can change its form. For example, light energy can be changed into heat energy. **Stored energy** can become **energy in action.**

Using a **force** takes energy. When forces move an object, work is done. If you cannot move an object by yourself, you can use simple machines to help you. **Pulleys** and **levers** are two kinds of such simple machines.

Gravity is one of the most important forces that start things moving. If there were no such force as gravity, nothing would stay down.

Friction makes things stop. When two things move against one another, there is friction. Knowing about friction can help us prevent many car and bicycle accidents. It can also help us prevent many accidents in the home.

Checklist of Science Words

Here are some science words you read about in this unit. Can you tell what you have learned about each one?

energy	friction	mechanical energy
energy in action	gravity	stored energy
force	lever	

Complete the Sentence

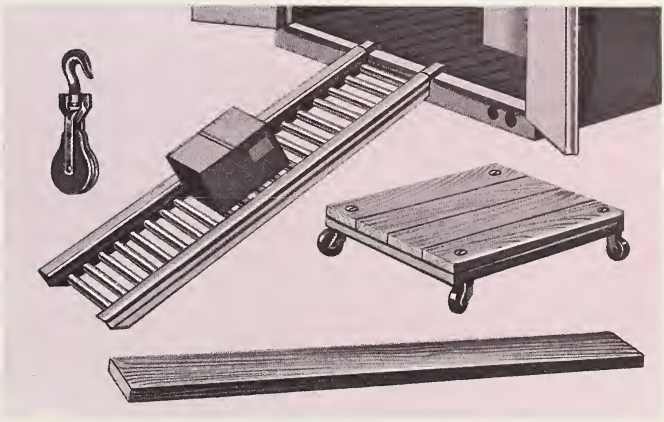
Write the numbers 1 to 5 in your notebook. Next to each number, write the answer that best completes each sentence below.

1. Almost all energy comes from the _____?_____.
2. The energy of motion is called _____?_____ energy.
3. The names of two simple machines that help us to move things are _____?_____ and _____?_____.
4. The force that makes things fall is _____?_____.
5. A force that slows things down is _____?_____.

What Would You Do?

Here are four pictures of simple machines. Tell which machine you would use to help you do each of the things listed below.

1. Lift a heavy rock.
2. Raise a flag on a flagpole.
3. Move a box filled with heavy books across the room.
4. Move something heavy from the street to the sidewalk.



YOU CAN LEARN MORE ABOUT

Understanding Energy

Unscramble the Letters

1. The ability to do work.
2. The energy of motion.
3. The opposite of hidden energy.
4. Energy that is hidden.
5. The push or pull on an object.
6. A simple machine that helps you to lift things.
7. The force that makes things fall to the earth.
8. A force that slows things down.
9. A form of energy.
10. Another form of energy.

1. GYREEN
2. INACHEMLAC NGEYRE
3. NGYREE NI TACINO
4. REDTSO REYGEN
5. CEROF
6. RELEV
7. TIVGRAY
8. NOCIRFTI
9. YECLTITERIC
10. DSUNO

You Can Make an Exhibit

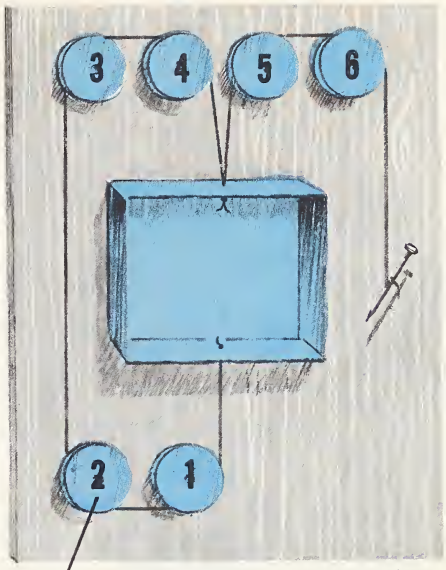
There are many things that help you use energy safely. You can collect them and make an exhibit. You may want to invite other classes to see your exhibit. Ask them if they can tell how the things in your exhibit help people to use energy safely.

You might collect such things as potholders, which protect you from heat energy, and insulated wires, which protect you from electrical energy.

You Can Build an Elevator

You will need a 1′ x 2′ piece of wood, 6 empty spools, 7 nails, a small cardboard box, and 2 pieces of string.

Attach the spools to the board as shown in the picture. Make holes at the top and at the bottom of the box. Put one piece of string through the hole at the bottom and knot it inside the box. Now, wind this piece of string around the spools as you see in the picture. Attach the second string to the first, and pass it over spools #5 and #6. Tie a nail to the end of the string. Turn spool #2 to operate your elevator.



You Can Read

1. *Your World in Motion* by George Barrow. The story of energy in its many forms.
2. *Thank You, Mr. Sun* by Hy Ruchlis. Shows how energy comes from the sun.
3. *Everyday Machines and How They Work* by Herman Schneider. Many different machines are shown.
4. *Simple Machines and How They Work* by Elizabeth H. Sharp. How simple machines are used.
5. *Now Try This* by Herman Schneider. Tells about many simple machines and how they work.

3

Living Things–Green Plants

Green Plants—The World's Food Makers

Green Plants—How They Survive

Green Plants—How to Grow Them

You have learned that you get your energy from the food you eat. In Unit 2 you learned that food has energy stored in it—energy that comes from sunlight. Energy is the ability to do work. The energy your body uses to do work comes from sunlight by way of green plants.

Green Plants—The World's Food Makers

Scientists call green plants the world's food makers. Let's see why. Make a list of the foods you had last night for dinner, and this morning for breakfast. How many of these foods come from green plants?

Our fruits and vegetables come from green plants. Foods like lettuce and spinach are the **leaves** of green plants. Still others, like cauliflower and broccoli, are the flowers of green plants. Corn and beans are the seeds of green plants. Foods like carrots and radishes are the **roots** of green plants. Asparagus is the **stem** of a green plant. Can you think of other foods that come from different parts of green plants?

Look over your list of foods again. Are there any foods on your list that do not come from green plants? Did you have meat for dinner? Meat certainly does not come from a green plant. But think carefully. What do cattle, sheep, hogs, and poultry eat? You are right if you said grain or grass

or seeds. All the foods for these animals are, or come from, green plants. Most of us enjoy eating steaks, hamburgers, chops, and chicken. These meats come from cattle, sheep, hogs, and poultry. So you see, not all our food comes *directly* to us from the plants themselves.

You can show step by step how all your food can be traced back to green plants. For example, did you eat eggs for breakfast? Eggs come from chickens, which get their food from corn. Corn is a seed of a green plant. You, in turn, eat the eggs laid by chickens. Now can you show step by step how some of the food you eat can be traced to green plants? You might start by tracing milk back to green plants.

What part of a green plant is each of these vegetables? How can you find out about them?

Animal Life Depends on Green Plants

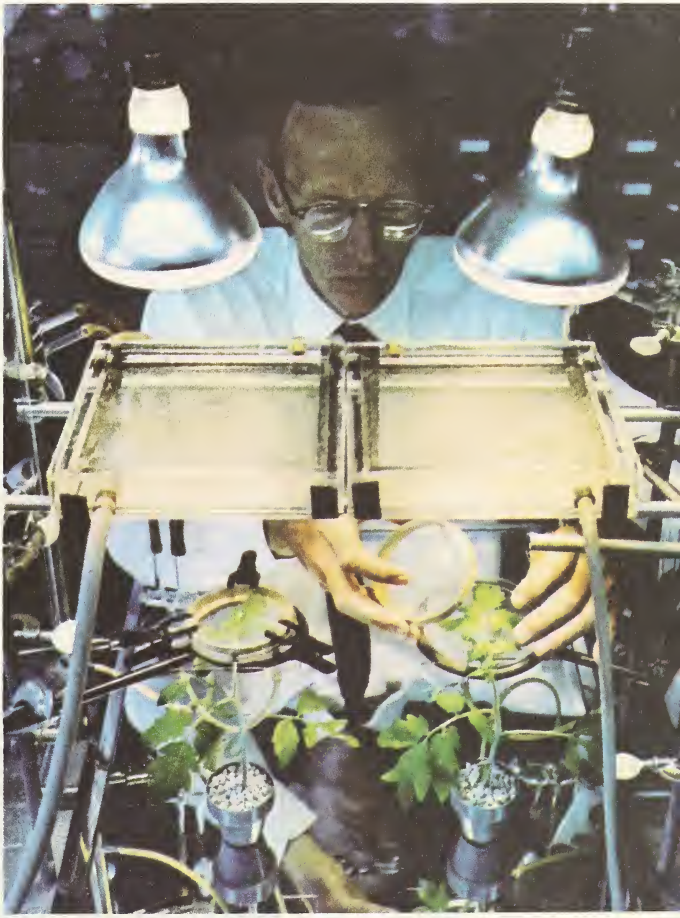
Large animals may feed on smaller animals, which, in turn, feed on plant life. For example, the polar bear eats seals for food. Seals eat fish. These fish feed on smaller animals. These smaller animals feed on green plants that live in the ocean.

Do you know why all animal life depends on green plant life? Animals cannot make their own food. Green plants can. Animals must have ready-made food, either from plants or from

The polar bear depends on green plants for its food. But it eats seals, and seals eat small fish. Explain, then, the first sentence.

smaller animals that eat plants. That is why you and all the animals on earth depend on green plants.

Right now, in laboratories in many parts of the world, scientists are doing experiments to find out just how green plants make their own food. They already know a great deal, and you will read about what they know. But there are still many questions to be answered. When scientists find the answers, people may no longer have to depend on green plants for food. Why will this be a great discovery?



Many scientists in many parts of the world spend a great deal of time studying green plants. When they find out how carbon dioxide and water combine in a green plant to make food, they will have made a major scientific discovery.

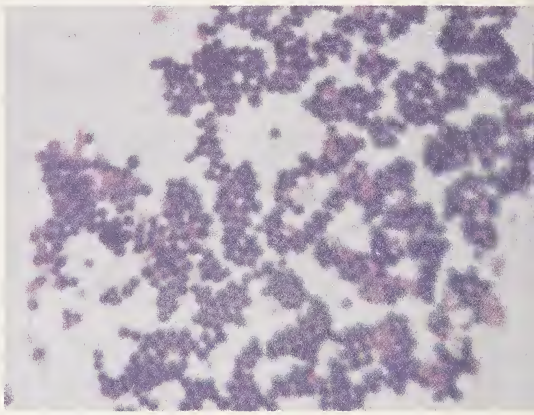
The "Green" in Green Plants

There are some plants that are not green. Mushrooms, bacteria, and a few flowering plants like beechdrops and Indian pipe are examples of plants that are not green. Do you know any others? Where do these plants get their food?

What makes some plants green? These plants, or parts of them, are green because they contain the green chemical **chlorophyll** (KLOR-uh-fil). Chlorophyll gives these plants their green color. Chlorophyll enables the green plant to make food.

None of these plants has the green chemical chlorophyll. Like animals, these plants must depend on green plants for their food. How do they get their food from green plants?

Mushrooms



Bacteria

Beechdrops

Indian pipe

Energy—from the Sun to You

Did you know that a plant *works* when it makes food? You know that it takes energy to do work. It takes energy to make food. Where does the green plant get energy?

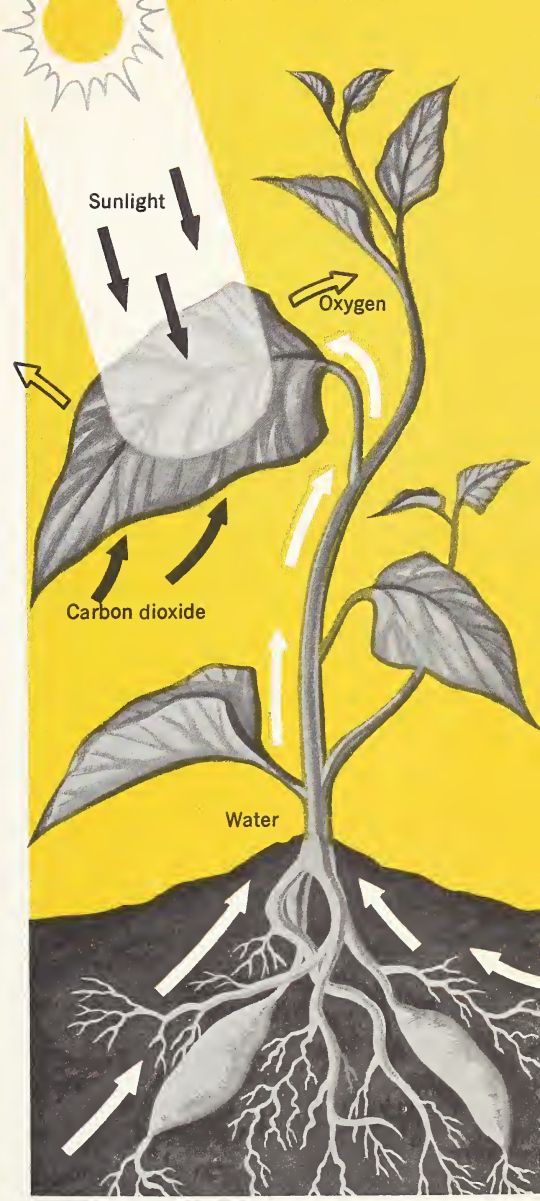
It is the light energy from sunlight that the green plant uses. You could say that the food you eat has the energy of sunlight in it, which is captured by the green plants. Can you trace the energy you use back to the sun through a green plant?

Let's review. Chlorophyll in green plants makes it possible for the plant to use the energy of sunlight to make food from materials in soil and air. You, in turn, get your energy from plants, or from animals that eat plants.

Now let's find out what kind of food a green plant makes.

The Food Green Plants Make

The food that green plants make is sugar. The making of sugar by green plants is called **photosynthesis** (foh-tuh-SIN-thuh-siss). The word photosynthesis comes from two Greek words—*photos,* meaning "light," and *synthesis,* meaning "putting together." During photosynthesis, **carbon dioxide,**



How do green plants get the materials they need to make food? What else does the picture show?

which is a gas, and water are *put together in light* to make a kind of sugar.

The sugar made by green plants is not the sugar you use at home. Although it is white, it is not nearly as sweet. It is the same sugar that you have in every living cell of your body. This sugar is called **glucose** (GLOO-kohss). All the glucose in the living cells of your body comes from food made by green plants.

Glucose is used by the plant to make other kinds of food. One of these foods is starch. How can we

PATHFINDERS IN SCIENCE

Jan Ingen-Housz

(1730–1799) Holland

Jan Ingen-Housz (ING-un-howss) was a medical doctor whose hobby was science. He was the first to investigate the process of photosynthesis.

In the summer of 1778, Ingen-Housz visited England. During the next three months he did 500 experiments. These experiments were remarkable. However, they were not really appreciated at the time because people did not fully understand their importance. Today's scientists believe that Ingen-Housz's experiments were the beginning of the modern study of photosynthesis.

Ingen-Housz published the results of his experiments in 1779 as "Experiments on Vegetables, Discovering Their Great Power of Purifying the Common Air in the Sunshine, and of Injuring it in the Shade and at Night." This is what Ingen-Housz wrote:

"I was not long engaged in this enquiry before I saw a most important scene opened to my view: I observed, that plants not only . . . correct bad air in six or ten days, by growing in it, . . . but that they perform this . . . in a few hours; . . . owing to the . . . influence of the light of the sun upon the plant. I found that plants . . . pour down continually . . . a shower of this . . . air, which . . . contributes to render it more fit for animal life; that this operation is far from being carried on constantly, but begins only after the sun has for some time made his appearance above the horizon, and has, by his influence, prepared the plants

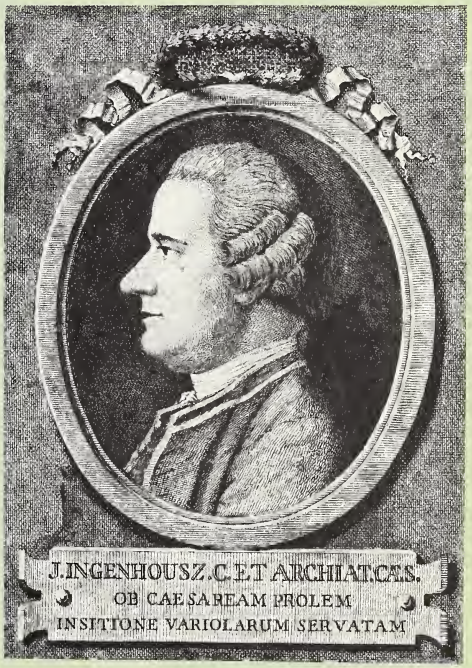
find out if starch is made in the green leaf? You can find out by placing a drop of iodine on the leaf. Iodine turns from brown to blue if there is starch. But the leaf that you will use is green, so you may not be able to see a blue color in the leaf. If you take off some of the green coloring, then you could test it for starch.

Did you ever get a green stain on your clothes after sitting in the grass? Some of the chlorophyll from the grass rubbed off. Do you think you can rub the chlorophyll off a leaf?

to begin anew their beneficial operation upon the air, and thus upon the animal creation, which was stopt during the darkness of the night. . . ."

The experiments which Ingen-Housz did showed that the green parts of plants perform the process of photosynthesis. He showed that green plants give off oxygen in sunlight and carbon dioxide in the shade and at night. He even observed chlorophyll in the green leaf.

One of today's leading researchers in photosynthesis, Dr. Eugene I. Rabinowitz, has said, "In photosynthesis, we are like travelers in an unknown country around whom the early morning fog slowly begins to rise, vaguely revealing the outlines of the landscape. It will be thrilling to see it in bright daylight." Jan Ingen-Housz was the first pathfinder to explore this unknown country.



EXPERIMENT

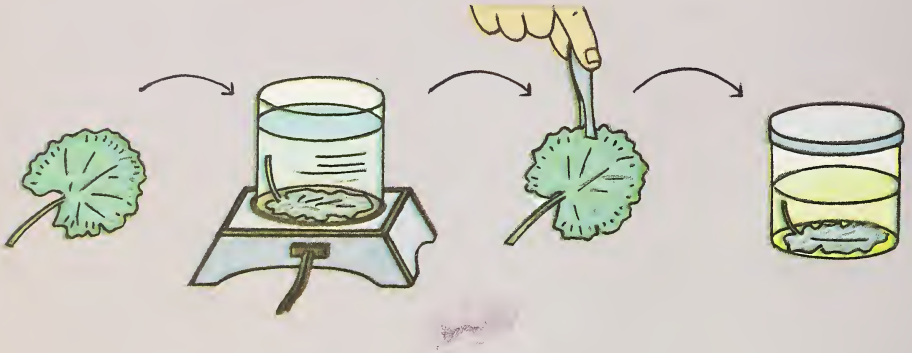
How Can Chlorophyll Be Removed from a Green Leaf?

What You Will Need

wide-mouthed glass jar and cover	small glass bottle	green leaves (coleus or geranium)
	hot plate	
	rubbing alcohol	

How You Can Find Out

1. Soften the leaves by boiling them in water.
2. Put some leaves in the jar and cover them with alcohol.
3. The next day, pour the alcohol into a small glass bottle.



Questions to Think About

1. What is the color of the leaves?
2. What is the color of the alcohol?
3. How did the chlorophyll from the leaves get into the alcohol?

The chlorophyll is now removed, and the leaves may now be tested for starch. Wash the leaves in water to get out any alcohol. Next drop some iodine on them with a medicine dropper. What happens? How can you find out if there is starch in a potato, in an apple, in a piece of bread, or in wheat flour?

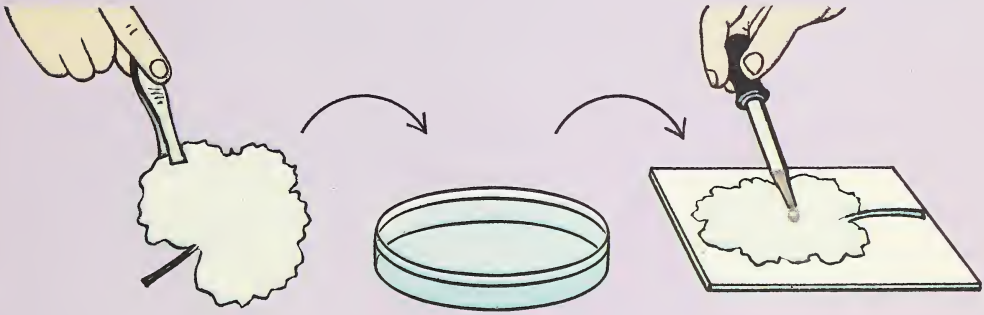
Do Green and Non-Green Parts of Leaves Have the Same Amount of Starch?

What You Will Need

iodine
rubbing alcohol
tweezers
coleus leaf (or any other leaf that is partly green and partly white)

How You Can Find Out

1. Remove the chlorophyll and wash the leaf.
2. Drop iodine on the part of the leaf that was green and on the part of the leaf that was white.



Questions to Think About

1. Does it look as if the green part and the white part of the leaf have the same amount of starch?
2. What does this experiment show?

Now try doing this. Take a leaf from a plant that has been standing in the sunlight for a few hours and test it for starch.

Do you think starch will dissolve in water? How can you find out? Try dissolving cornstarch or the kind of starch used for starching clothes.

EXPERIMENT

Do Green Plants Need Light to Make Food?

What You Will Need

green plant (coleus or geranium)
iodine
rubbing alcohol
water

How You Can Find Out

1. Test two or more leaves of the plant for starch.
2. Water the plant well.
3. Place the plant in a closet for two days.
4. After two days, test two or more leaves for starch.

Questions to Think About

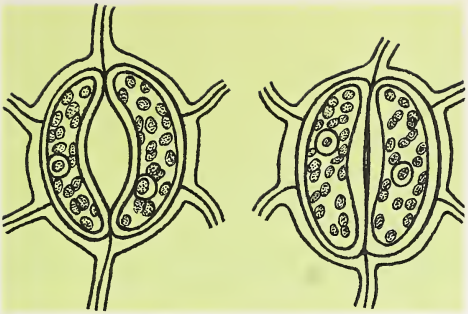
1. Which leaves have less starch in them? What does this show?
2. Why can some plants grow in shady places?

Besides starch, green plants also make proteins and oils from glucose. Soybeans are rich in proteins. Rub a peanut between your fingers. How does it feel? Peanuts and cottonseed have much oil in them.

How Plants Use Food

Some of the food that the plant makes is used by the plant itself. It uses the food in the same ways that your body uses food. It uses food as fuel for energy. It uses food to grow new cells and to repair old cells. Food that is not used right away may be stored in the plant's stem, roots, and other parts. So the next time you eat celery, remember that you are eating food that the celery plant stored in its stem. And when you eat a carrot, you are eating food stored in the root of a carrot plant. Now do you see that the food the green plant makes for itself is the same food that you use for energy, growth, and repair of your body?

Let's review. Green leaves use the energy from sunlight to make glucose. Some of this energy is stored in the glucose. Glucose and the foods made from it contain energy from sunlight.



Tiny openings on the underside of plant leaves.

Leaves

You learned that the green plant needs carbon dioxide and water to make glucose. The carbon dioxide that the plant needs enters the plant through the *leaves.*

On all leaves there are hundreds of tiny openings. These openings are about 2,000 times smaller than a pinhole. It is through these openings that air enters the leaves. The plant uses the carbon dioxide that is in the air. On many leaves, there are many more openings on the underside of the leaf than on the upper side. Can you tell why? However, the leaves of a water lily have most of the openings on the upper side. Can you tell why?

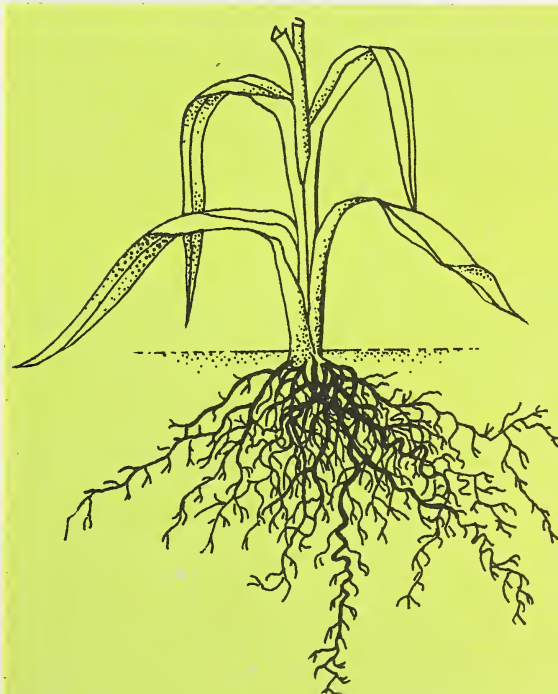
We have been studying what happens in just one part of a green plant—the leaf. Let's now take a closer look at some other parts of the plant.

Roots

Now let's find out how the green plant gets water. The water it needs to make food and grow is in the soil. If you dig up a plant, you will find that there are many "branches" on the part that grows in the soil. These branches are called *roots.* They spread out into the soil and absorb, or soak up, the water that is needed by the plant.

When you plant seeds, tiny roots soon spread out into the soil and absorb the water needed by the plant. You can see how this happens.

How do roots spread out in the soil? How does this arrangement help them take in water?



EXPERIMENT

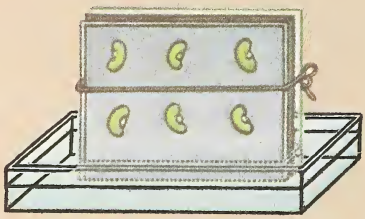
How Do Roots Grow?

What You Will Need

corn or bean seeds pan of water two pieces of glass
blotting paper

How You Can Find Out

1. Soak the corn or bean seeds overnight.
2. Wet the blotting paper and place the seeds on it.
3. Put the blotting paper between two pieces of glass.
4. Put the pieces of glass in a pan of water so that the blotting paper will be kept wet.
5. Let the glass remain in the pan for several days.



Questions to Think About

1. Why do you need to use blotting paper?
2. What do the roots look like?

You can also watch roots grow if you put stems or cuttings of certain kinds of plants in water. Your mother may put pieces of ivy or other plants in water before she plants them in soil. This is called "rooting" the plants. If a glass container is used, you can see what happens after the plant has been left in the water for a while.

Have you ever put part of a carrot or a sweet potato in water? This is another way to watch roots grow. What is the chief difference between the experiments on pages 70 and 71?

How Do Roots Grow?

What You Will Need

a carrot or a sweet potato pan of water

How You Can Find Out

1. Cut off about an inch from the top of a carrot or from one end of a sweet potato.
2. Put this piece in a pan of water with the cut end of the piece down.
3. Do not cover the whole piece with water.

Questions to Think About

1. What is the first thing to grow out of the plant?
2. How does the piece of plant get water?
3. How long did it take for roots to grow?

If you look at the roots of plants with a magnifying glass, you will see tiny root hairs that spread out into the soil. You can see these root hairs on the bean plants or the corn plants you have been observing. They absorb water and minerals from the soil.

Stems

From the roots, the water and minerals travel up the *stem*. You cannot see the minerals in the water. You cannot see the water and minerals traveling through the stem, unless you add some coloring to the water.

EXPERIMENT

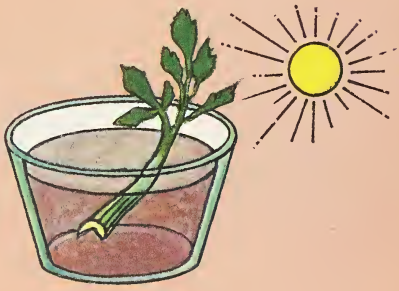
How Do Water and Minerals Travel Through the Stem?

What You Will Need

water	celery	red or blue
knife	glass jar	vegetable coloring

How You Can Find Out

1. Mix the red or blue vegetable coloring with water.
2. Put a piece of celery into the colored water.
3. Cut off the end of the celery *while it is under the water.*
4. Place the jar of colored water in sunlight for several hours.



Questions to Think About

1. What happens to the red or blue coloring mixed with water?
2. How does water from the soil travel up the plant?

Stems also hold up the plant. Have you ever seen garden plants drooping in the sun? This may happen when plants are losing water faster than they can get it from the soil. This shows that they need water to help support them.

Stems also carry the food made in the leaves to other parts of the plant. Just as the cells of your entire body need food to live and grow, so do the cells of the entire plant. All living things must have food.

Green Plants Store Food

Some of the food made by a green plant is used by the plant to live and grow. The rest is stored in the plant's roots or stem or seeds.

Some plants, such as the carrot, the sweet potato, the beet, and the radish, store food in their roots. When you eat these vegetables, you are eating the food that the plants have stored in their roots.

Some plants store food in underground stems. For example, the white potato is really the underground stem of the potato plant. It contains the starchy food that the green part of the potato plant makes. How can you be sure that the potato is storing starch? Is it also storing other foods?

The **bulb** in plants such as onions and tulips is made up of leaves growing around each other. You can see them if you cut an onion in half from top to bottom. The growing part of the bulb is in the center. Around it are very thick leaves. They are not green, as most leaves are. They do not make food, as green leaves do. But they do store food.

If you put an onion in water in a warm, dark place for several days, you can watch green leaves grow out of the top. The food stored in the thick leaves of the bulb helps them grow.

All plants store some food in their seeds. When seeds are planted, this food keeps the new plant alive inside the seed until it can make its own food. You saw how this happened when you planted bean and corn seeds.

We use many seeds for our own food. We use the seeds of beans, peas, and corn. We eat the seeds and the seed containers, or fruits, of other plants, such as cucumbers, eggplants, peppers, squash, and tomatoes.

How does the stored food in the leaves of the bulb help the young plant to grow and develop?

Using What You Have Learned

1. Susan and her parents went to her grandmother's farm for Sunday dinner. They all ate these things:

fruit salad	peas and carrots
chicken soup	rolls and butter
celery and olives	lettuce and tomato salad
roast beef	chocolate layer cake
baked potatoes	milk

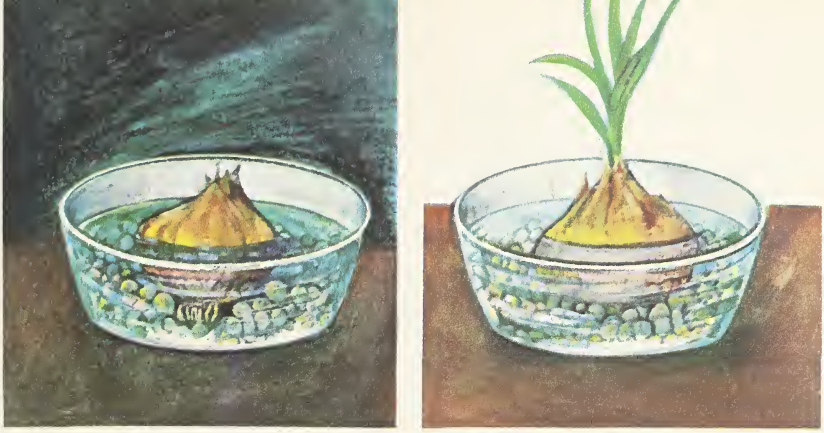
   At the end of dinner, Susan said, "We couldn't have had a thing to eat today if it were not for green plants." Her grandmother asked Susan to explain. How might Susan trace each food they ate back to green plants?

2. We use many kinds of seeds for food. We also eat the seed containers, or fruits, of some plants. Look at the list of plants below. Pick out the seeds that you eat. Pick out the seed containers that you eat. Which foods on this list are not seeds or seed containers?

lettuce	eggplant	carrots
corn	tomatoes	cucumbers
lima beans	cabbage	peas
squash	turnips	peanuts

3. Suppose that you have a house plant that was healthy and green when you got it. Suddenly it begins to droop, and a few leaves begin to turn yellow. What may be the causes? What might you do to save the plant? What will you try first? Why?

4. You can raise plants such as the narcissus and hyacinth from bulbs. Plant the bulbs in a bowl, with pebbles to hold



Why do bulbs begin growing better in dark places than in sunny places? Why shouldn't you completely cover the bulb with water?

them. If you plant more than one in a bowl, do not let the bulbs touch each other. Use enough water to come up to the bottom of the bulbs.

Put two or three pieces of charcoal in the bottom of the bowl. They will keep the water from smelling unpleasant when the brown leaves of the bulbs begin to rot.

Put the bulbs in a dark place until they begin to grow. Then put them in the sun and water them. Why can you not let them go on growing in the dark?

5. Get four flowerpots of the same size and number them. Plant five bean seeds in each one. Put flowerpot 1 on the windowsill, and water it every day. Put flowerpot 2 next to flowerpot 1, but do not water it. Put flowerpot 3 in a closet, and water it every day. Put flowerpot 4 in a closet, but do not water it.

Keep a daily chart, for three weeks, of how much each plant grows. Which plant grows best? What do plants need to grow?

Green Plants—How They Survive

There are plants to be found on almost every part of our planet. There are plants on the coldest parts of the earth. There are plants on the warmest parts of the earth. And there are plants living on parts of the earth where there are many changes in temperature during the year. These plants are able to live through very hot temperatures in the summer and below-freezing temperatures in the winter.

Some Plants Survive the Winter

Most trees and shrubs bloom and grow during the months of spring, summer, and fall. When winter comes, the leaves fall and the food made within them moves to those parts of the plants that are not hurt by freezing. During these cold months, there is very little growth.

There are, however, some plants that remain green during the coldest days of winter. The pine tree is one such plant. A pine tree is known as a woody plant. Can you name other plants that are woody? Even though some plants stay green during the winter, they do not grow as rapidly or make as much food as they do in warmer months.

Many plants that are not woody, such as some garden plants, only partly die in the winter. The parts that die are all above the ground. But other parts of the plant, below the ground,

How does the pine tree survive the winter months? What happens to the tulip during the winter months? What happens to each of them when summer comes?

remain alive. In spring, the parts above the ground appear again. Can you tell which parts of these plants stay alive during the winter? If only the parts of the plant below ground remain alive in winter, do you think the plant is better able to survive? Why?

Some Plants Can Survive with Little Water

Plants and animals need water to live. Animals can move to another place when water becomes scarce. Plants cannot do this. How, then, do plants survive?

The cactus is a plant that grows in very hot, dry places. A cactus plant can live for long periods of time without rain. How is the cactus plant able to do this? Look at the picture on this page. Do you see any leaves on the cactus plant? Look at the stem. See how wide it is. The roots are very close to the surface of the ground. When it rains, the roots can quickly take the water the plant needs and store it in the stem. The stem can hold a supply of water lasting many months.

Some plants grow in soil that does not hold a great deal of water. Plants that live in this kind of soil do not lose much water. Do you know why? Pine trees can live in sandy soil, which holds little water. Pine trees have narrow leaves. How does this help them to save water?

Some cacti can live for more than a year on just one heavy rainfall. How is this possible?

You have been reading about some of the ways plants are able to live through heat, cold, and dryness. Farmers who grow plants for food cannot depend on these ways only. Can you tell why this is so?

One way to protect shrubs from the cold is shown here. How does this method work?

Man Protects Plants

Because we depend on plants for our food, we must depend on the farmers who raise crops for food. They, in turn, must grow healthy plants to earn a livelihood. They must do everything they can to make certain their plants stay healthy.

Farmers and flower growers have learned many ways to protect plants. They have learned these ways from plant scientists, who keep finding new and better ways to protect plants from heat, cold, diseases, and animals.

Plant scientists help not only the farmer but also the gardeners who grow and sell flowers. Scientists help people who enjoy growing flowers and vegetables for fun and beauty. Let us now find out how scientists help people to protect plants.

Protecting Plants Against Heat and Cold

Have you ever seen young plants in a garden with baskets or paper coverings over them? This is one way some young plants are protected from the hot sun. They are shaded until their roots can get the water they need.

Have you ever visited a greenhouse where some plants are grown until it is warm enough to plant them outdoors? Cabbage and tomato plants are grown in greenhouses. The sun shines through the glass roof and sides of the greenhouse. The glass protects the plants from cold and storms, but it lets the sun shine on the young plants. The sun heats the soil in the greenhouse. How does this heat the air?

Many plants are kept in greenhouses until it is warm enough for them to be planted outdoors.

These fungi are found on the sides of trees. Can you find out the name of the fungi?

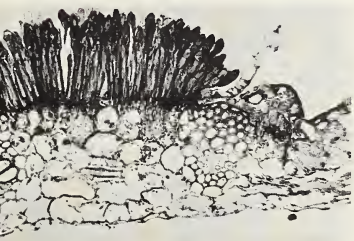
Protecting Plants Against Disease

You have heard of the bacteria which sometimes cause disease. Bacteria belong to the group of plants called **fungi** (FUN-jy). Fungi are plants that do not have chlorophyll. They cannot make their own food. They must feed on animals and on other plants. They are so tiny you need a microscope to see them.

Some bacteria are useful in the garden. They help to put minerals containing nitrogen into the soil. Plants need nitrogen to live and grow.

Other bacteria are harmful to plants. They cause plant diseases. Have you ever seen gardens where some plants have withered and died from plant diseases? Plant diseases can ruin valuable crops on farms.

On the left are wheat rust spores as they look under a microscope. In the center you see the spores on a wheat plant. On the right is a fungus that affects rose plants, called black spot smut. Both rust and smut are diseases that destroy plants.



On the left is the apple borer, which destroys apple crops. On the right are plant galls, which cause plants to lose food materials. These galls may be caused by bacteria, fungi, viruses, or insects. Have you ever seen such galls on plants?

There are many kinds of diseases that attack plants. Some diseases attack fruits and vegetables. Others attack flowers. Some attack our crop plants and forest trees.

There are ways we can keep diseases from attacking plants. Scientists have made sprays and powders that kill the bacteria before they can do any harm. Other sprays kill the insects that carry the bacteria from the diseased plants to the healthy ones. Farmers, aided by state and local agricultural agencies, know exactly the right time to spray.

Once a disease attacks a plant, the plant becomes dangerous to the healthy plants around it. Plant growers help plants get rid of some diseases by spraying the plants or by using a powder on them. Often they remove and burn the diseased parts of the plants.

Protecting Plants Against Weeds

If you have a garden, you know that plants must also be protected from **weeds.** Weeds are plants that grow where they are not wanted. Some weeds you may know about are crab grass and dandelions. Can you name some other weeds? Weeds crowd out other plants. They usually grow faster than the useful plants. Weeds will grow in your garden if you are not careful. They will use some of the water and minerals that your garden plants need.

Some weeds grow so tall that they will keep garden plants from getting the light they need. You will have to get rid of them before they get a chance to produce seeds. If you do not, still more weeds will grow. What are some ways to get rid of weeds?

These plants are all weeds. Can you name them? How will you go about finding their names?

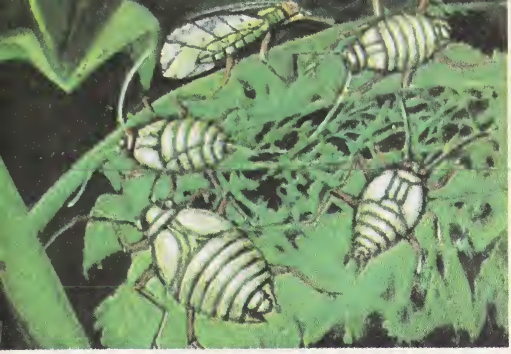
How do the three animals shown harm plants in different ways? Can you tell what each does that will harm or destroy the plants?

Protecting Plants Against Animals

There are still other enemies of plants besides weather and disease. These enemies are animals.

Some birds eat young plants. Many insects destroy leaves or fruits. Gophers or ground squirrels destroy grain, grass, young plants, and fruit trees. Rabbits gnaw away at young peach or apple trees during the cold winter.

All these animals feed on plants or seeds. Some of them, like the Japanese beetle and the tent caterpillar, are harmful and must be destroyed. Others, like the bird and rabbit, must just be kept from harming plants.



Aphids pierce leaf tissue and draw out the plant's juices with their sucking mouth parts.

In this picture you see beetle larvae, known as grubs. Grubs cause decay in many plants.

Insects damage plants in different ways. The grasshopper eats leaves, buds, bark, roots, stems, and fruits of plants. Some insects cannot chew, but they suck juices from plants. These are called sucking insects. Others, like the tent caterpillar, eat the leaves of trees.

Protecting Plants Against Harmful Insects

Insects destroy more plants than any other animals do. They destroy almost as many trees each year as forest fires. Scientists, farmers, gardeners, and people who grow flowers or vegetable gardens at home are always fighting these enemies of plants. If you want to grow flowers or vegetables, you will have to fight them, too.

In order to protect plants from harmful insects, we must first know how these insects live and grow. The way they live and grow is called their **life history.** Every plant and animal has a life history. If farmers and gardeners know the life history of harmful insects, they can find out when and how such insects can be destroyed more easily.

The gypsy moth is a harmful insect. It is harmful to many trees, especially apple trees. The mother moth lays her eggs on the leaves of an apple tree. As each egg hatches in the early spring, a little caterpillar comes out. It eats the young leaves of the apple tree and grows until its skin is too small for the rest of its body. Then it sheds its skin for a new one. It keeps on eating and growing. It grows several

skins in this way. While it is eating and growing, it destroys many leaves.

Then it stops eating leaves and spins a cocoon of silk thread around itself. It stays in its cocoon until certain bodily changes occur. Then it comes out of the cocoon as a moth.

When do you think the farmer would try to destroy the gypsy moth? Would he wait until the moth comes out of the cocoon? No. Then it would be too late. The farmer sprays his apple trees in the early spring when the eggs are hatching.

The farmer sprays poison on the leaves. When the caterpillars eat the

Laying eggs

Larva

Pupa

LIFE CYCLE OF THE GYPSY MOTH

Adult male

Adult female

leaves, they die. The farmer's apple trees, which are not affected by the poison, will then blossom and bear fruit unless some other enemy attacks them.

Insect sprays are poisonous. They do not always kill only the *pest*. Some sprays are so powerful that they kill almost all the wildlife when a whole region is sprayed. These sprays can also be harmful to man. People must be very careful about how they spray, how much they spray, and what kind of spray they use.

Insects such as aphids cannot be destroyed by poisoning their food. These insects suck juices that are *inside* the

Millions of locusts live underground, sucking juices from tree roots, until they develop into adults and all push their way to the surface at the same time. They molt into winged insects and slit tender twigs in which to lay eggs.

parts of the plants. Poison sprayed on the outside of the leaves would not kill them. So the farmer uses a spray that kills the aphids when it touches them.

Sometimes the farmer traps some of the insect enemies of his plants. Japanese beetles can be trapped. You can trap them yourself. Hardware stores sell traps for them. The traps are glass jars with metal covers. The beetles can get into the jar, but they cannot escape.

Some Insects Help Plants

Even though some insects destroy plants, you should not try to kill every insect you see. Some insects help plants. Bees and other insects carry pollen from one flower to another. Pollen is needed by plants to make new plants.

The bee brushes against the parts of the flower bearing pollen and becomes dusted with the pollen, which it carries to other flowers.

The praying mantis eats grasshoppers, flies, mosquitoes, and other harmful insects. The ladybird beetle fights the cottony-cushion scale, an insect that destroys orange and lemon trees in California. Since ladybird beetles were not found in California, scientists brought them all the way from Australia to destroy the scale. The ladybird beetle is often called the ladybug.

The ichneumon (ik-NYOO-m'n) wasp lays its eggs in the skin of the larvae of some insect pests such as the sphinx moth. When the wasp larvae develop, they eat the insides of the pest larvae and then form pupas on the skin of the pest. These wasp larvae are very useful to man, for they prevent damage to plants by other insects. What other insects help plants?

Praying mantis

Ladybird beetle

The woodpecker's stiff tail acts as a brace. Its deeply curved claws clutch the rough tree bark. Its beak is as hard as a chisel. Powerful muscles in the head and neck of the woodpecker enable it to drive its beak with hammer-like blows into the tree. A long tongue with pointed barbs hooks any insect the woodpecker finds.

Birds Both Help and Harm Plants

Birds save the farmers of our country millions of dollars each year. They do this by destroying many of the insects which harm plants. Woodpeckers eat the insects that dig their way into the bark of trees. Swallows are birds that catch insects in the air. Many of the songbirds live mostly on insects.

In the spring, you can see birds bringing insects to the young birds in their nests. They make many trips all day long, carrying one or more insects on every trip.

If birds did not eat so many insects, there might be too many for the farmer to fight. Some insects lay so many eggs at one time that it is hard for us to imagine what would happen if all of them grew.

Although birds help in the battle against insects, they do not always fight on the side of the farmer. Sometimes birds dig up some of the farmer's seeds before the seeds have a chance to start growing. Some birds eat young plants in the spring before there are enough insects to eat.

We have to protect our gardens from birds, but we do not have to kill the birds to do this. Can you think of ways to protect a garden from birds?

Using What You Have Learned

1. You can collect insects with a homemade net made from a piece of wire, a broomstick, and some cheesecloth or curtain goods. Use your net to collect the kinds of insects you would like to watch.

   Once you catch the insects, you will need a place to keep them. You may want to use an insect cage. An easy way to make a cage for small crawling insects is to make a screen around the top of a flowerpot filled with moist soil. Use wire screening rolled up and fastened together. Be sure that there are no openings. Cover the top with cheesecloth or curtain goods. Keep grass or small plants growing in the moist soil.

2. Grasshoppers destroy many useful plants. Find out about their life history. When is the best time to destroy them? What would be a good way to get rid of them? These books may help you to do your report:

   The Grasshopper Book by Wilfrid S. Bronson
   Grasshoppers and Crickets by Dorothy Childs Hogner

With a parent along to help, these children are collecting insects and other small animals. Animal and plant collecting is a good way to learn a great deal and to enjoy the great outdoors.

Green Plants—How to Grow Them

You have learned how green plants grow and how they are protected from weather, diseases, and animals. Now let's use what we have learned to start a vegetable garden. You will need to find out what kinds of vegetables will grow best in your garden. Some vegetables grow best where the summers are long and warm. Some vegetables grow better in one kind of soil than in another. How can you find out where different vegetables will grow best?

The Kind of Soil You Will Need

Every package of seeds tells you what kind of soil is needed for the seeds to grow well. Most soils are made up of very small pieces of rock. Such pieces of rock in soil are so small that you cannot see them easily. Other soils have larger pieces of rock in them. Look at some soil with a magnifying glass. Do you see small pieces of rock? There are other things in soil too. Do you know what they are?

Soil is made up of many materials. Examine soil from many places. How can you learn what materials are found in the soil that you examine? What would be a good source?

Can you explain what is happening in this picture? Which soil is sandy and which has humus in it?

Some soils have a great deal of sand in them. Others have a great deal of clay in them. You can feel the difference between clay soil and sandy soil. Sandy soil feels rough when you rub it between your fingers. When clay soil is dry, it feels smooth, almost like a powder.

Clay and sand are also different when they are wet. Clay forms a sticky lump. When it dries, it gets very hard. Sand does not hold the water. The layer of sandy soil dries very quickly.

Sand, clay, and humus together make up **loam.** Most of our good soil is loam. It is darker than sand or clay. It does not stick together like clay. It holds water for plants better than sand does. **Humus** (YOO-muss) is formed from plant and animal material that decays. When plants die, their roots decay. Their leaves and stems become mixed with the soil, and then decay. The remains of decayed plants form humus.

Humus adds minerals to the soil. It helps the soil to hold more water and keeps it from becoming dry and hard. Humus also increases the amount of air space in the soil. Why is this important? Mixing manure or decayed leaves with soil is a good way to add humus to it.

You can measure the amount of water that different soils will hold.

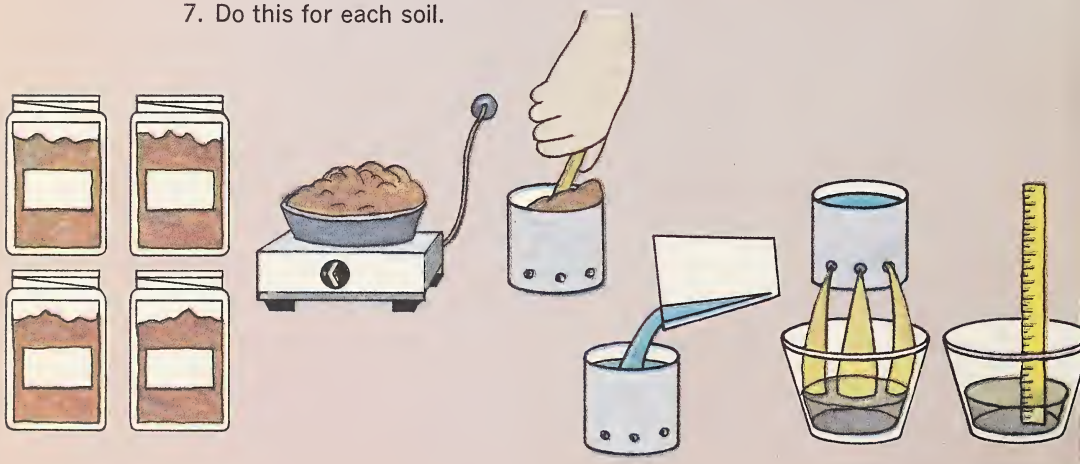
Do Different Soils Hold Different Amounts of Water?

What You Will Need

different kinds of soil
a few tin cans
pan
water
electric hot plate

How You Can Find Out

1. Collect several jars of soil from different places and label each jar.
2. Dry out each soil by heating it in a pan over a hot plate.
3. Punch small holes at the bottom of a can and fill it exactly half full with one of the soils.
4. Pack the soil down lightly.
5. Fill the can to the top with water.
6. Collect the water that runs through the holes at the bottom of the can. Measure the amount.
7. Do this for each soil.



Questions to Think About

1. Which soil let the most water go through?
2. Which one held the most water?
3. Which do you think is the best soil to plant your seeds in?

Starting Seeds

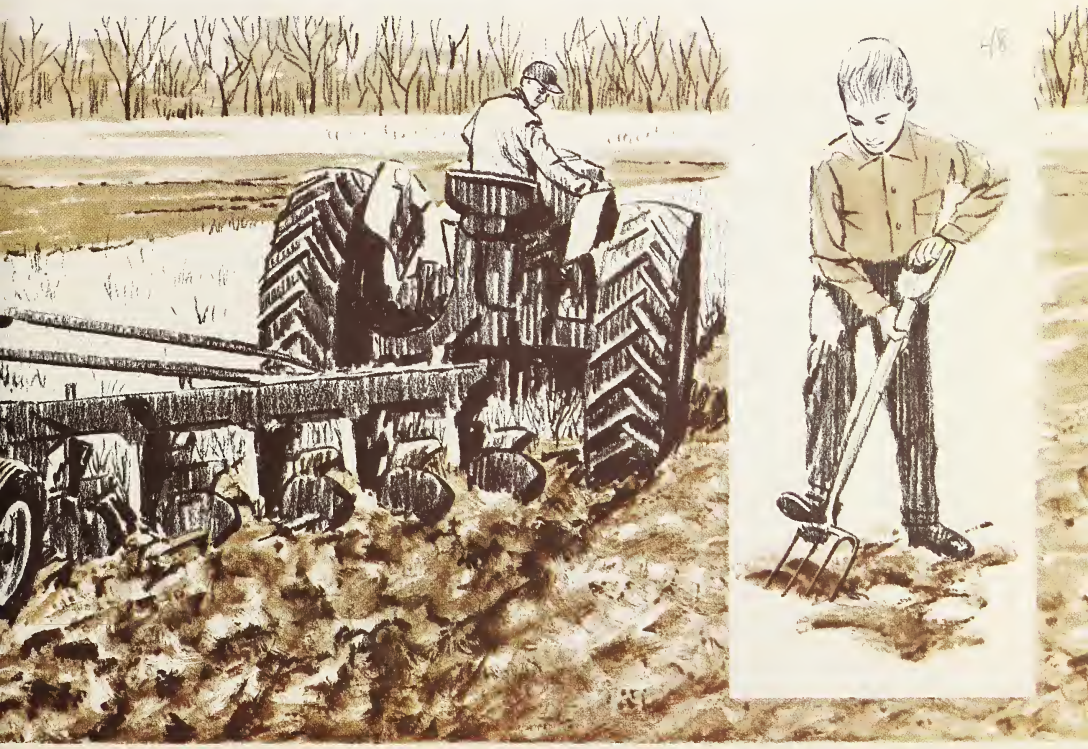
When seeds are planted, they must get air and water. The little plant inside the seed needs both to grow. If bean seeds in a glass are covered with water, they will not grow properly. That is why you were told on page 70 to use moist blotters to get the seeds started.

When you plant seeds, you must make sure that they will get enough air. Before planting the seeds, you should loosen the soil. In this way, more air can get into the soil.

Loosening the soil also helps the little plant in other ways. When the plant begins to grow, its stem and roots can push and spread through the soil more easily. It will be easier for water to get into the soil.

After the seed is planted, loose soil should be pressed around it. Particles of soil must touch the seed on all sides. Can you tell why this is important?

In these pictures, you see two ways to loosen soil. Can you tell why it is important that this task be done before seeding? What else needs to be done before seeding?



Adding Minerals to the Soil

Plants need minerals. They get their minerals from the soil. Each time vegetables are grown on a farm or in a garden, the vegetables take away some of the minerals from the soil. We get the minerals our bodies need when we eat plants.

After a while, the mineral supply in the soil becomes low. If it gets too low, plants will not grow well.

Before this happens, a good gardener or farmer adds minerals to his soil. He may use manure from animals or decayed leaves and plants. He may use chemical **fertilizers** (FER-til-yz-erz). Fertilizers are rich in important minerals needed by plants.

A home gardener fertilizes his lawn after checking with his county agricultural agent.

An agricultural scientist checks soil samples. He can tell the condition of the soil.

A gardener may have his soil tested for minerals before he plants his seed. He takes a little soil from his garden and sends it to the county agricultural agent. There the soil is tested by plant scientists. They tell him what kind of fertilizer he should put into his soil to make sure that his garden will grow well and will produce good crops.

Adding Water to the Soil

If a garden does not get enough rain, it has to be watered. It is not enough to sprinkle it lightly with a hose. Why is it important to see that the water gets down into the soil?

What time of day do you think would be best for watering your garden? Why is the middle of the day not a good time?

The picture at the right shows the kind of sprinkler you might find on a farm or a nursery. Home gardeners can attach sprinklers to garden hoses.

Sprinklers are a good way to water gardens and lawns without much effort.

Using What You Have Learned

1. Make a plan for a garden in your neighborhood. The answers to these questions will help you make your garden a success. Where would be a good place for one? What vegetables will grow well in your climate? How and when should the seeds be planted? Who will prepare the soil? Will it be necessary to water it? How will you water it? Will the soil have to be fertilized? How can you find out?
2. Some soil is not good for gardens because it has too much acid in it. You can find out if soil is acid. Mix water with the soil. Put a piece of blue litmus paper, which you can buy in a drugstore, halfway into the mixture. If the soil is acid, the water will turn the paper pink. Test soil from many different places to find out whether it is acid. Find out what you should do with acid soil.

WHAT YOU KNOW ABOUT

Living Things—Green Plants

What You Have Learned

Green plants are the world's food makers. All animal life depends on green plants.

Chlorophyll gives green plants their color. Plants with chlorophyll use the light energy from sunlight to make food from water and **carbon dioxide.** This process is called **photosynthesis.** The food that green plants make is a sugar called **glucose.** Glucose is used by the plant to make other kinds of foods. Glucose and the foods made from it have the energy of sunlight stored in them.

Carbon dioxide needed by the green plant enters through tiny openings in the **leaves.** Water and minerals enter through the **roots.** **Stems** carry food and water to all parts of the plant.

Green plants store the food that they do not use in their roots, stems, or seeds so that the food can be used at another time.

Because man depends on green plants, he must make certain his crops are healthy. Plant scientists find ways to protect plants from weather, diseases, animals, and insects.

We must protect plants from many animals that destroy them. But we must also protect the many kinds of animals that are helpful to growing plants. Some birds eat harmful insects. Some insects, such as the bee, help flowers to make new plants. Some insects destroy harmful insects.

In order to grow healthy plants, we must plant them in good soil. Most of our good soil is **loam.** Sand, clay, and **humus** make up loam. Sometimes a farmer must use chemical **fertilizers** to add minerals to the soil.

Checklist of Science Words

Here are some science words you read about in this unit. Can you tell what you have learned about each one?

bulb	glucose	photosynthesis
chlorophyll	humus	roots
fertilizer	life history	stems
fungi	loam	weeds

Find the Answer

Write the numbers 1 to 6 in your notebook. Next to each number, write the word that best completes that sentence.

1. Carbon dioxide enters the plant through openings in the ___?___.
2. The part of the plant that spreads out into the soil is called the ___?___.
3. Food and water are carried up the ___?___.
4. The ___?___ take up water and minerals from soil.
5. The ___?___ supports the plant.
6. Glucose is made in the ___?___ of a green plant.

Complete the Sentence

Write the numbers 1 to 5 in your notebook. Next to each number, write the answer that best completes that sentence.

1. The green chemical that makes plants green is ___?___.
2. Green plants get energy from the ___?___ to make food.
3. The food that green plants make is ___?___.
4. A plant may store food in its ___?___, ___?___, and ___?___.
5. The best kind of soil to grow plants in is ___?___.

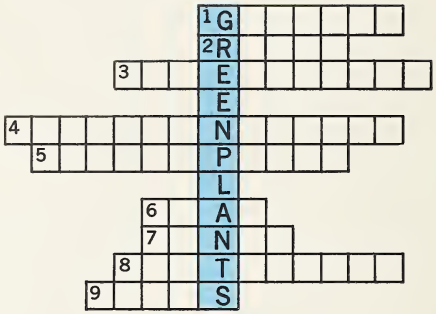
YOU CAN LEARN MORE ABOUT

Living Things—Green Plants

What Are the Words?

Write the words in your notebook.

1. Sugar that green plants make.
2. They get water from the soil.
3. How insects grow and change.
4. The putting together of carbon dioxide and water, in sunlight, to make sugar.
5. Green plants need this chemical to make food.
6. The best kind of soil.
7. Plants that cannot make their own food.
8. This is added to the soil to give it minerals.
9. Material formed from decayed plants and animals.



Can You Tell?

Mr. Burns will not get good crops this year because he has not taken good care of his fruits and vegetables. Look at the picture of Mr. Burns's farm and tell how many things you can find wrong.

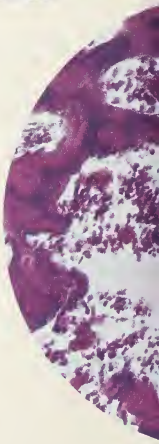
You Can Make a Terrarium

You will need plants of different sizes, stones or pebbles, twigs and bark, nuts, pine cones, charcoal, and soil.

Put about an inch of soil in the bottom of the tank and wet it a little. Next, put the larger plants into the tank. Then put in the smaller plants. Finally, arrange the rest of the things in the tank. Sprinkle it with water. You should keep the soil damp, but never wet. Use pieces of charcoal in your terrarium to remove odors. To finish, put a piece of glass across the top of the tank.

You Can Read

1. *The First Book of Plants* by Alice Dickinson. You will learn how plants make food, grow, and reproduce.
2. *All About the Flowering World* by Ferdinand C. Lane. Descriptions of many unusual plants.
3. *Plants in the City* by Herman and Nina Schneider. Tells about plants that grow in the city.
4. *The Wonderland of Plants* by Terry Shannon. Tells the life stories of many different plants.
5. *Play with Plants* by Millicent E. Selsam. How to do simple experiments to learn about plants.



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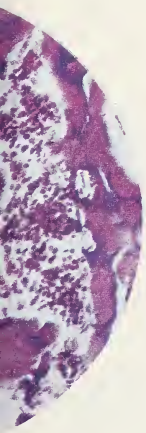


Animals–Simple and Complex

Being Alive

Animals—A Closer Look

Animals—How They Are Grouped

Look at the pictures. Can you pick out the things that are alive? Look again at the pictures. What are the differences between something that is alive and something that is not alive? You will find out in this unit. When you find out, you will know what it means to be alive.

Being Alive

What do you need to stay alive? How might you find the answer to this question? One way might be to find out what things plants and animals need to stay alive.

Do Living Things Need Oxygen?

Do plants need air? Does a horse need air? Do you need air? Do rocks need air? Plants take in air all the time. Horses breathe all the time. So do you. Do rocks breathe?

Living things need **oxygen** to stay alive. Oxygen is a gas that is found in the air. Plants and animals need oxygen to live. They get their oxygen from the air around them. You learned that green plants need carbon dioxide for photosynthesis, but they also need oxygen in order to live. Plants and most animals that live in the water have a way of getting their oxygen from the air that is in the water. *All living things need oxygen to stay alive.*

How many living things do you see?

WHICH ARE ALIVE?

How can you tell which things in each picture are living?

Do Living Things Need Food?

Food is used for energy and for growth. The food that living things eat supplies them with stored chemical energy. You learned about this when you learned about green plants.

A plant does not get its food in the same way as a horse or a bird or a person. A plant gets materials from the air, from the soil, and from water. The plant uses these materials to make its own food. Animals get their food from green plants or other animals that have eaten green plants. *All living things need food to stay alive.*

Do Living Things Need to Get Rid of Wastes?

When living things use oxygen and food, they form wastes in their bodies. These wastes must be removed, or they will poison the living things.

Your lungs, your skin, and your kidneys help remove the wastes from your body.

All animals and plants must get rid of their wastes. Even tiny plants and animals, so small that they can be seen only with a microscope, must get rid of their wastes. *All living things must get rid of wastes to stay alive.*

Do Living Things Produce Other Living Things?

Look again at the pictures on pages 102 and 103. Where do new plants come from? Where do new birds come from? Now look at the automobile. Where do new automobiles come from?

Plants can produce more plants. Birds can produce more birds. Horses can produce more horses, and people can produce more people. But an automobile *cannot* produce another automobile. *Only living things can produce other living things like themselves.*

"What does it mean to be alive?" Let's review. All living things need oxygen. All living things need food. All living things must get rid of wastes. Living things can produce more living things like themselves.

The Life Activities of Living Things

To stay alive, all living things must carry on certain **life activities.** You have just learned about some important life activities—using oxygen, using food, and getting rid of wastes. Producing more living things is also a life activity. But it is different from other life activities.

If a living thing does not have oxygen, does not have food, or does not get rid of wastes, it will die. A living thing will not die just because it does not produce more living things like itself.

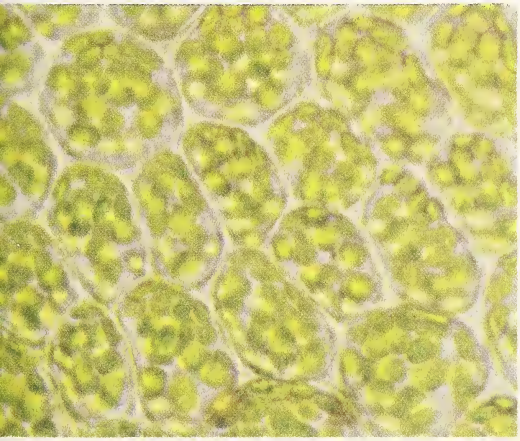
But what would happen if all living things did not produce more living things like themselves? What would take the place of the living things that died, or were eaten by other living things, or were destroyed by enemies?

All the life activities of living things —using oxygen, using food, getting rid of wastes, producing more living things like themselves—use energy. Where does this energy come from? The energy is given off by the burning of food within the living things. The food for animals comes from green plants or from animals that have eaten green plants. Green plants, as you already know, make their own food by using energy from the sun.

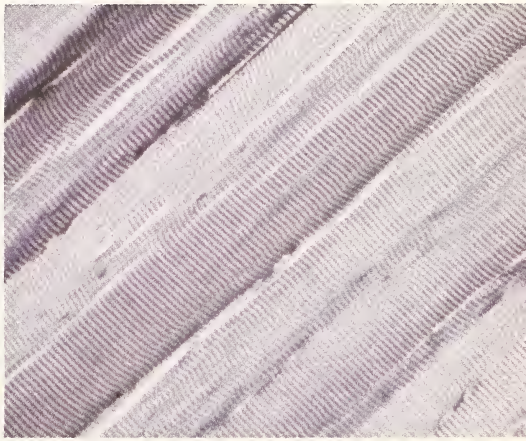
All Living Things Are Made of Cells

You have learned that plants and animals are living things. This means that they are alike in some important ways. You have already learned that both plants and animals carry on life activities. Another way in which they are alike is that both plants and animals are made up of **cells.** A cell is a tiny unit of living material.

These cells are from a green plant. What do you see inside each plant cell?



These are muscle cells from a human body. Where do you think you have such cells?



There are many kinds of cells. Compare the pictures on these pages. How are these cells alike? Remember that the pictures you see are hundreds of times larger than the real cells. How do you think scientists are able to see real cells if the cells are so small?

Think of cells as building blocks. If you were making houses out of blocks, you could make the houses any shape or size that you wanted. You could do this by using more or fewer blocks, or by arranging the blocks in different ways. No matter what the shape or the size of the houses you made, all the houses would be made out of these blocks. This is also true for all living things. No matter what the shape or size of a living thing, it is always made out of cells. The cell is the building block of all living things.

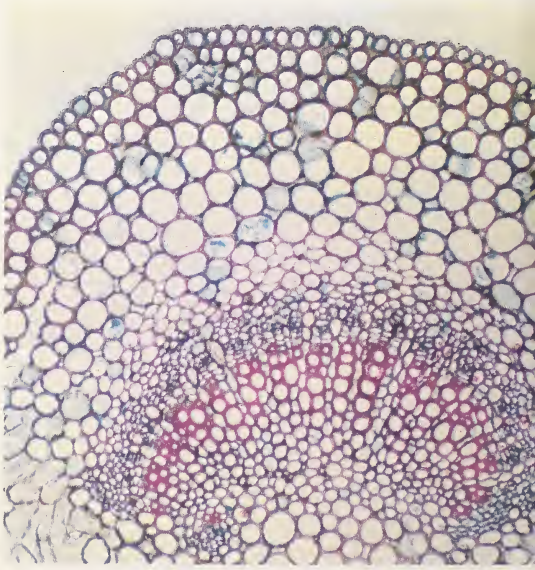
Some plants and animals are only one cell, but others are made up of millions of cells. You will be learning more about cells as you learn more about living things.

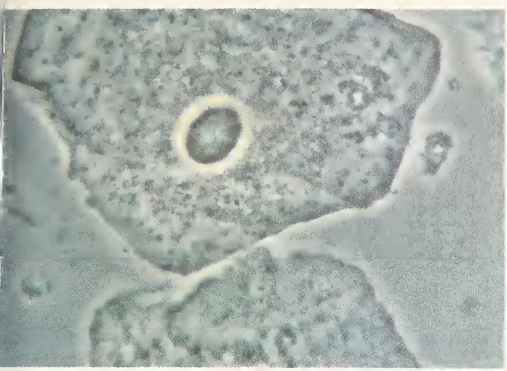
How Plants and Animals Differ

Look again at the pictures of the plant and animal cells. Compare them. Do you see any difference between the plant and animal cells? Notice the thick, firm wall around the plant cells. Do you see any such wall around the animal cells?

There are other important differences between plants and animals. Green plants, as you already know, make their own food. Do you remember how they do this? Animals cannot make their own food. The animals that you know move about from place to place. The plants that you have seen growing must stay in one place.

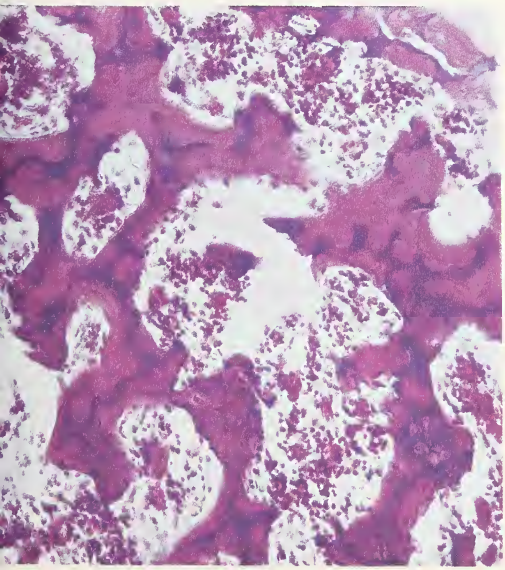
Some of the cells you see in this picture carry food and water to parts of the plant.





PLANT AND ANIMAL CELLS

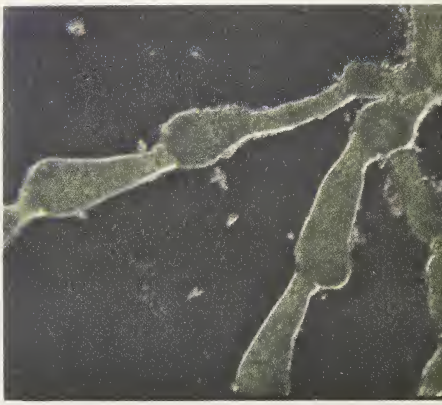
What differences do you see among the cells? Can you tell which are plant cells and which are animal cells? How do you know?



Could a scientist see root cells by looking at a root? How do you think he studies the cells shown?

WHAT ARE THEY?

Can you identify the living things on this page? What can you find out about each one? How will you go about finding out about them?



Did you know that there are plants that cannot make their own food? There are also plants that can move and animals that seem to stay in one spot. So you see, even though plants and animals are different in many ways, it is not always easy to tell them apart. In some cases, it is very hard even for a scientist to say which is a plant and which is an animal.

Is It Plant or Animal?

You are going to make a **survey.** A survey is a way to get information. Scientists make surveys. When scientists make a survey, they try to get information. They keep a written record of what they find.

You can make a survey of some living things. You can make a survey of how many kinds of living things can be found where you live.

When you make your survey, you may want to make a chart like the one below. It will help you keep a record of the plants and animals you find.

Name of Living Thing or What Living Thing Looks Like	Where Seen	Date Seen

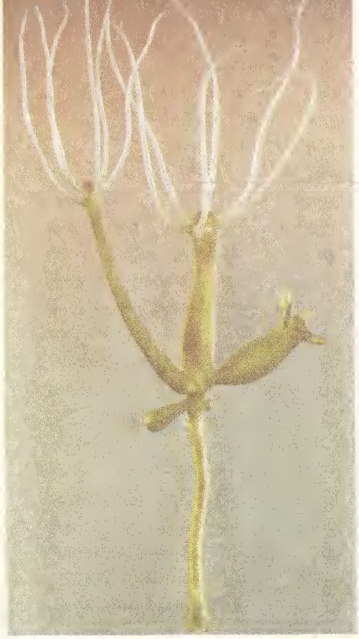
Any time is a good time to look for and study plants and animals.

Where will you look for plants? Where will you look for animals? Look everywhere. Look on the ground and in the ground, on trees and in trees, in the air, on the walls outside your house and in your house, on ponds, and on lakes.

Before you begin your survey, there is one very important question you must be able to answer. Can you tell which living things are plants and which are animals? Let's see. On the next two pages you will see some pictures of living things. Compare the pictures. Then make a record in your notebook. Write the names of the plants in one column and the names of the animals in another column.

PLANTS OR ANIMALS?

Which are plants? Which are animals? In your notebook, write the names of the animals in one column, the names of the plants in another column. Tell why you grouped each living thing the way you did. Do you find that some living things are hard to group?



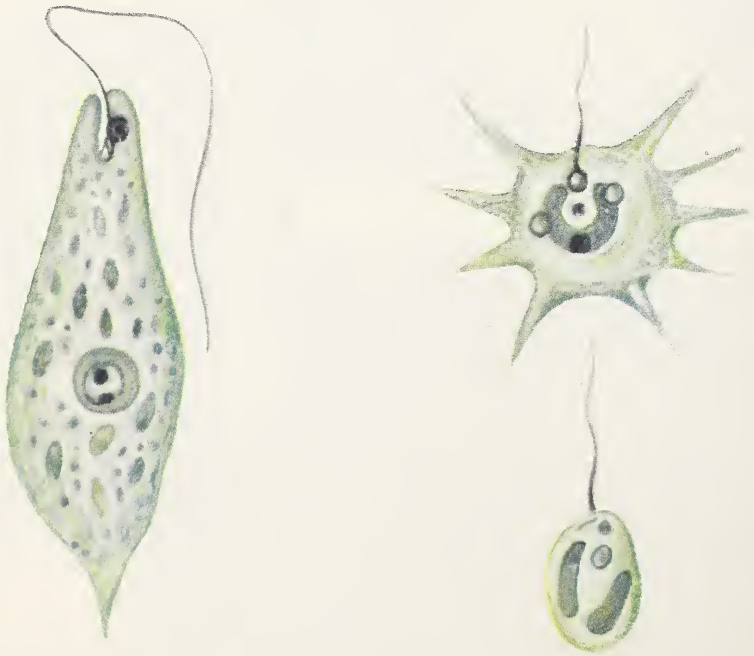
Now look at these two pictures of living things.

The pictures show how these two tiny animals look when we see them under a microscope. The **euglena** (yoo-GLEE-nuh) is often found in ponds. Sometimes there are so many of them that the top of the pond looks green. The euglena makes its own food, as do green plants. It has chlorophyll within its body, and it can carry on photosynthesis. However, it can swim like some animals.

The **chrysamoeba** (KRISS-uh-mee-buh) also depends on photosynthesis for food. However, there are times when it moves about and feeds, as do some animals.

You now know why scientists sometimes find it difficult to know which living things are plants and which are animals. Whenever scientists find a new living thing, they must compare it to the living things they know about. How does this help them to find out what it is?

On the left is a euglena. On the right are two views of a chrysamoeba. The top view shows it moving about and feeding as an animal does. The bottom view shows it when it is dependent on the process of photosynthesis.



Using What You Have Learned

1. Take a piece of paper and divide it into two columns. At the top of one column, write "Things That Are Alive." At the top of the other column, write "Things That Are Not Alive." Now look at the list below. Put the name of each object in the correct column. How do you know which things are living and which things are not?

elephant	pencil	book
rock	tree	fish
ant	automobile	grass
train	rosebush	puppy

2. Write a report on one of these animals: horse, spider, eagle, or seal. Tell how it carries on its life activities.

Animals—A Closer Look

As you compared living things, you found out in what ways they were alike and in what ways they were different. To compare one kind of living thing with another kind, you must study both kinds carefully. First you have to decide what things to observe. Then you have to decide how to observe them.

Suppose that you want to compare the sizes of two animals. Will it be enough to take a look at them and say that one is big and the other is small? What will you have to do? Suppose that you want to compare the way two animals move. Will it be enough to watch them and say that one swims and that the other runs? What will you have to look for?

Before you make a comparison, it will help you to make a list of the things you want to observe.

Comparing Two Animals

Let's compare an earthworm with an insect. Perhaps your class can collect enough earthworms and insects so that everyone will have one of each to observe.

If it is not too cold, you can find earthworms and insects such as ants, ladybugs, or butterflies in many different places. A good place to look for earthworms and ants is underneath rocks or boards that have been left on the ground.

If you cannot collect earthworms and insects, use these pictures to help you with your comparison.

As you observe the two animals, try to answer these questions:

How are their shapes different?
How long is each one?
Which one has legs? How many?

If you have live earthworms and insects, answer these questions:

How does the earthworm move?
Which has the softer body?

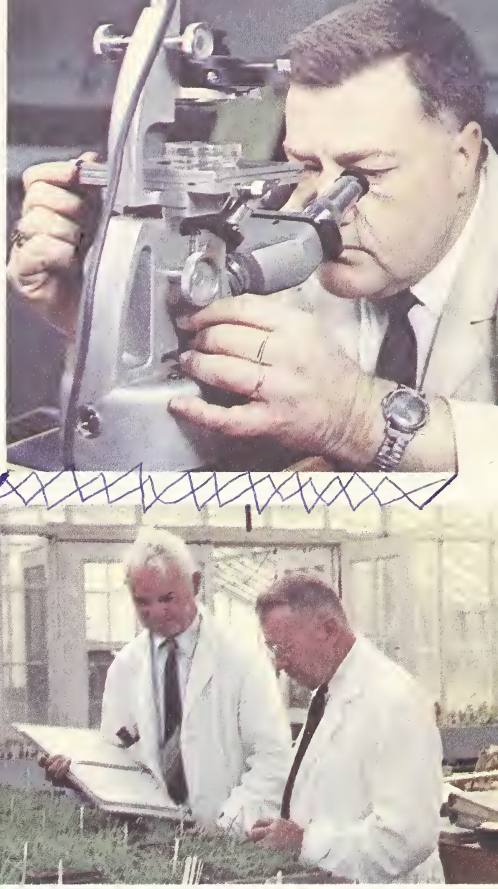
Here are some other questions you might not answer so easily. You would have to observe both animals for a long time to find the answers:

What does each one eat?
Where does each one spend the winter?
How does each one produce other animals like itself?

A good way to observe earthworms and ants is with a magnifying glass. What would you have to do if you wanted to see these animals under a microscope?

But there is another way you could find the answers to these questions. You could read what scientists who study living things have written about these animals. Such scientists are called **biologists** (by-OL-uh-jists), and **biology** (by-OL-uh-jee) is the study of living things. When a biologist studies an animal, he observes it for a long time. He keeps a carefully written record of what he finds out. He compares his record with the records of other biologists, to make sure that his observations are correct.

The information that biologists have gained through observation is printed in books. How would you find books about earthworms and insects?



Biologists use many instruments, study other scientists' records, and discuss their findings.

Animals—Simple and Complicated

When a biologist compares animals, he finds that some are **simple** and some are **complicated.** A simple animal has few parts. A complicated animal has many different parts. It is like comparing machines. Suppose that one machine has only two parts and another has twenty parts. Which would you say is simpler? Which would you say is more complicated? In the same way, an animal with only a few parts is simpler than an animal with many parts.

You are now going to make a careful comparison of three animals. As you study these animals, try to find out how they are alike and how they are different. You should also try to find out how each animal carries on its life activities.

As you compare, remember that the scientist uses the word *animal* in a way that may be different from your use of the word. You have probably used the word *animal* for such living things as horses, cows, dogs, monkeys, lions, and cats. Some boys and girls think that only living things that walk on four legs are animals. But when a scientist talks about animals, he means *all living things that are not plants.* Be sure you know the difference.

A duck is an animal. So is an earthworm. So is a ladybug. Can you name other living things that boys and girls don't usually think of as animals?

To help you know if something is an animal, ask yourself these questions:

Is it alive?

Does it move about?

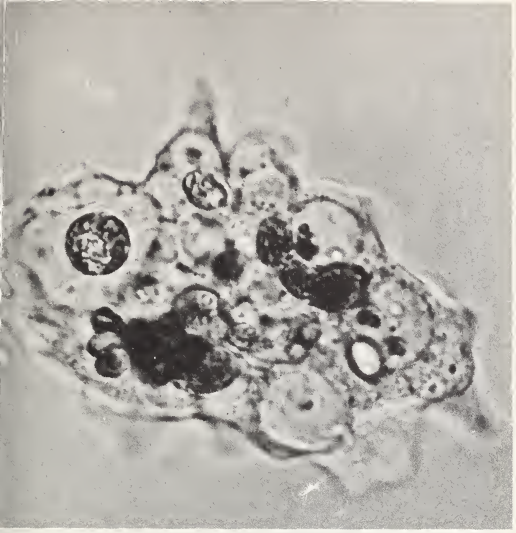
Does it depend on green plants for food?

It is not always easy to tell if a living thing is a plant or an animal. But the questions above will help you to tell which is which.

A One-Celled Animal

The simplest animals are those that have only one cell. An **ameba** (uh-MEE-buh) is a one-celled animal. It can only be seen through a microscope. An ameba looks like a very, very small piece of live gray jelly with a dark spot inside it.

What things do you think the ameba needs in order to live? What things do you think the ameba can do?



Above you see an ameba, and to the right you see it feeding. Can you describe how it feeds?

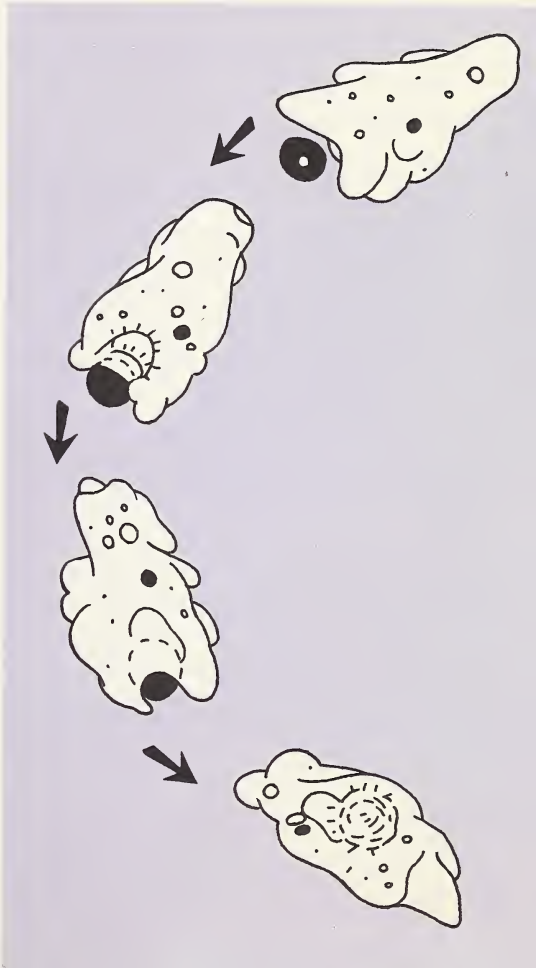
The ameba cannot live outside of water. It gets its food and oxygen from the water. Food, oxygen, and water pass through a thin covering which is the outside of the ameba's body.

Waste materials pass out through the ameba's thin covering. This covering is very special. It lets only certain things in and out.

The ameba catches its food by wrapping itself around the food. Look at the picture to see how it does this. The food then passes into the inside of the ameba, where the ameba can make use of it. From what you know about living things, can you tell what use the ameba makes of food?

The ameba, which is only one cell, can take in oxygen, eat, get rid of wastes, and produce more amebas.

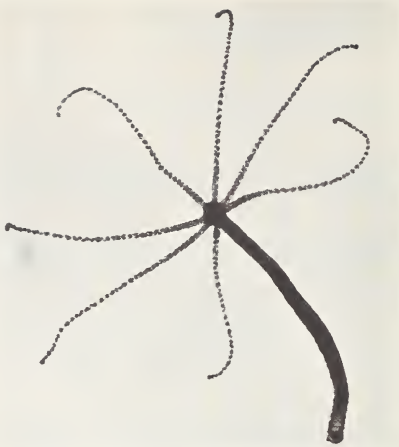
The ameba moves about. It has been seen to move as much as one inch per hour—a long trip for this tiny animal.



A Simple Many-Celled Animal

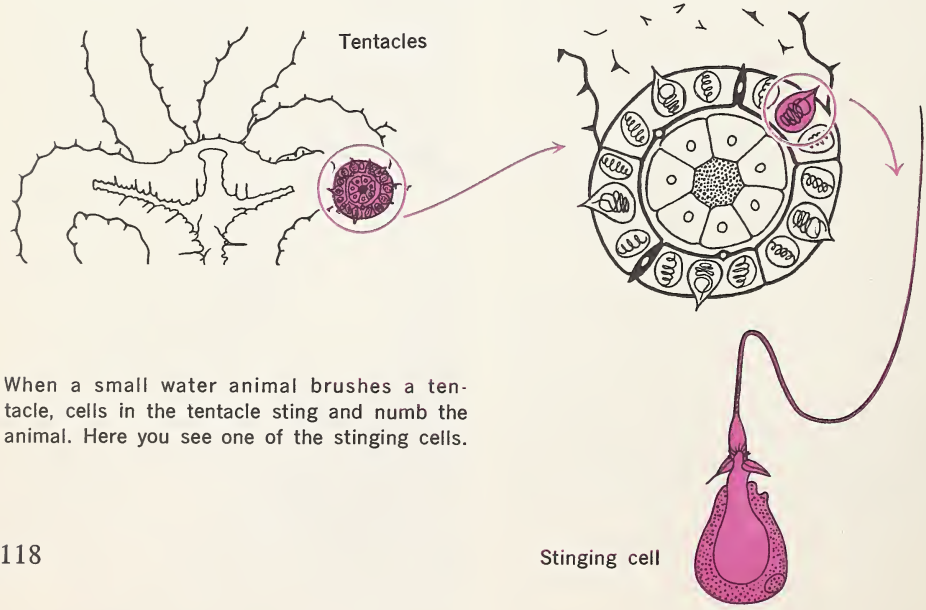
Attached to the rock in the picture is a little animal called a **hydra** (HY-druh). The hydra's stringy arms are called **tentacles** (TEN-tuh-kulz). Hydras, which are about half an inch long, are found in streams and in ponds. The hydra, like the ameba, gets the oxygen it needs from the water. But, as you will see, a hydra is a more complicated animal than an ameba.

To examine a hydra you would need a microscope. A hydra's body is made up of two layers of cells. The drawing shows how they are arranged. The cells in the outside layer protect the cells in the inside layer.

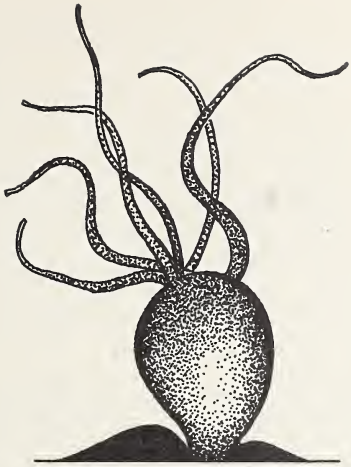


The hydra's body gives off a sticky material, which it uses to "glue" itself to water plants.

Some of the outside cells can shoot out poisonous threads that numb the smaller animals on which the hydra



When a small water animal brushes a tentacle, cells in the tentacle sting and numb the animal. Here you see one of the stinging cells.



When danger threatens, the hydra draws itself into a small knob. How does this protect it?

feeds. The tentacles then pull the food into the hydra's mouth. They act somewhat like a rubber band, except that nothing has to stretch them. They stretch themselves. The tentacles can do this because the cells of the tentacles can make themselves shorter or longer.

Some of the cells that line the inside of the hydra break up the food that the hydra catches. After the food is broken up, the other cells of the hydra can make use of it.

When the hydra is in danger, it pulls its body into a little knob. But how does it "know" when it is in danger? Some of the hydra's cells are able to sense when food or danger is near them. These cells are called **nerve cells.** They pass along a message to the cells that move the hydra's body.

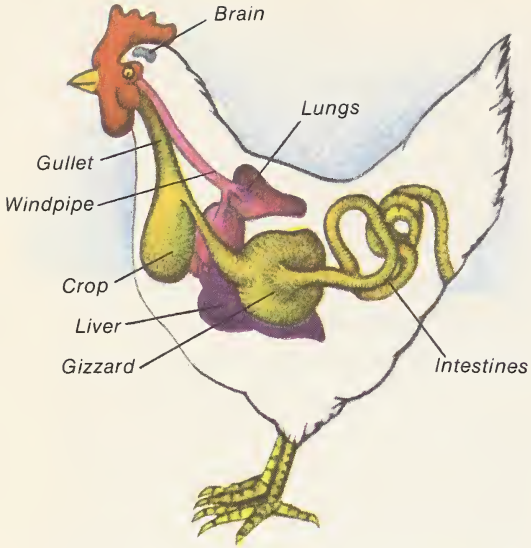
Some of the hydra's cells support or hold together other cells. Such cells are sometimes called **connective cells.**

The hydra is called a many-celled animal because it is made up of different kinds of cells. These different cells do different jobs. The hydra is a *simple* many-celled animal. There are other many-celled animals, such as the chicken, that are more *complicated* than the hydra.

A Complicated Many-Celled Animal

The chicken is a much more complicated animal than the hydra. Like the hydra, the chicken is made of many cells.

A chicken has many different parts —among them are wings, neck, and legs. Can you name some other parts? When you take a closer look at these parts, you find they are made up of skin, flesh, and bone. A chicken also has lungs, a stomach, a gizzard, a heart, intestines, and other parts. The hydra has none of these.



What are the parts of the chicken? Which parts are like those of your body?

Each part of the chicken is made up of different kinds of cells.

The fleshy parts of the chicken are the chicken's muscles. What do the chicken's muscles do? What do your muscles do? Each thread of chicken flesh is made up of many **muscle cells**. These are long, stringy cells that are held together by connective cells.

Examine an uncooked chicken leg. Notice how the skin is fastened to the flesh underneath it. What kind of cells hold the skin to the flesh? Remove some of the flesh from the bone. Separate some of the flesh into strings. How is the flesh fastened to the bone?

Chickens know what is going on around them. If they are frightened, they will cackle, try to fly, or run. An ameba and a hydra cannot do any of these things. Chickens can act in these ways because their nerve cells send messages to the muscle cells in their throats, wings, and legs. Muscles move when they receive messages from nerve cells to do so.

Your body has many of the same parts that a chicken has. You have skin, muscles, blood, bones, nerves, and a brain. All these parts of your body are made up of many different kinds of cells. These cells are very much like the special cells in the chicken.

The one-celled animals, such as the ameba, are the simplest. As the number of cells and the kinds of cells increase, the animals become more complicated. That is why the hydra is more complicated than the ameba and the chicken is more complicated than the hydra.

As you have read, all animals do certain things. You have also read that some animals can do more things than others. The hydra can do more things than the ameba. The chicken can do more things than the hydra.

You can do more things than the chicken. In fact, you can do more things than any other animal. You can talk, write, think, and even change things in the world around you. Only human beings can do all these things. There are no other animals and no plants that can do these things. Yet all living things, no matter how complicated or how simple they are, must carry on the same life activities to stay alive.

Using What You Have Learned

1. Make a comparison of a whale and a dog. You might try to answer some of these questions: How does each one move? How does each one get its food? How does each one get oxygen? How are their shapes different? These books might help with your report:

   The First Book of Mammals by Margaret Williamson

   The Great Whales by Herbert S. Zim

   Paws, Hoofs, and Flippers by Olive L. Earle

   All About Whales by Roy Chapman Andrews

2. If you have an aquarium, you can watch amebas and hydras with the help of a microscope. You may be able to see other small animals and plants. With a medicine dropper, take some water from the bottom of your aquarium. Put a drop of water on a slide and put the slide under the microscope. Your class can take turns looking at the water under the microscope. Let each pupil tell what he sees.

Animals—How They Are Grouped

Let's suppose that somebody gives you a handful of coins and tells you to sort them. How would you go about doing it? You would probably pick out all the pennies and put them in one pile; then you would do the same for the nickels and dimes and all the other coins. When you were finished, you would have separate piles of pennies, nickles, dimes, quarters, and half dollars.

You might use other ways to sort your coins. You might sort them according to their dates or even according to the metal they were made of. You would have a way in which to sort every coin you collected. Each time you got a coin, you would know in which pile to put it. You would know because you would already have worked out a **system of classification** for your coins. A system of classifi-

Here you see many different stamps. How many different ways can you group these stamps? Each stamp is numbered. On a page in your notebook make a column for

1

2

3

4

5

6

7

8

cation is a way of sorting things into groups so that you know where each thing belongs.

Librarians also use a system of classification. Have you ever asked a librarian for a book about a famous person? She knows just where to look for the book. Have you ever noticed that all the science books are in one section of the library and all the story books are in another section? The system of classification used by librarians helps them find books quickly. When a new book comes into a library, they know just where to put it. Can you imagine a library without a system of classification?

The System of Classification Used by Scientists

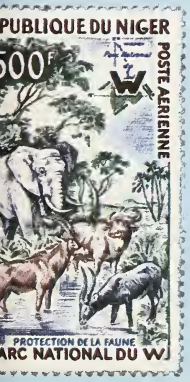
Scientists who study plants and animals have a system of classification. Let's see if you can tell what their system is. On the next two pages are pictures of living things. How would you sort these living things?

each group. Place the number of each stamp in the proper column. When you finish, you will have a system of classification. How many different systems can you make?

10

11

12



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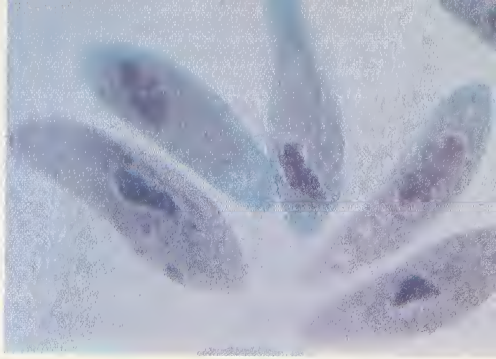
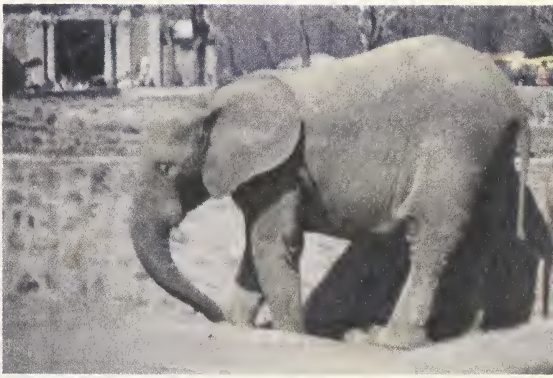
CLASSIFY THESE LIVING THINGS

Here you see ten living things. Make a system of classification for these living things.

Do you have any trouble classifying these living things? Scientists once did. Can you tell why?





Did you put all the plants into one group and all the animals into another group? If you did, you are on the right track. Scientists sort all living things into two large groups—*Plants* and *Animals*.

How Animals Are Classified

Scientists sort all animals into two large groups. They put all the animals that have backbones into one group and they put all the animals that do not have backbones into the other group.

Do you know what a backbone is? Feel the bones in the back of your neck. Run your fingers down your back. Do you feel the bones that make up your backbone? Your backbone is not one bone but 33 bones. Do you think that you could move as you do if your backbone was one bone?

If you stroke a cat or pat a dog on its back you can feel its backbone. Birds have backbones, and so do rabbits, squirrels, turtles, frogs, toads, and snakes. Snakes can move as they do because their backbones are made up of many bones. Some snakes have more than 300 bones in their backbones.

Make two columns on a piece of paper. At the top of one column write *Animals without Backbones.* At the top of the other column write *Animals with Backbones.* Into which column would you put these animals: hydras, chickens, amebas, earthworms, insects, oysters, birds, fish, human beings?

Each bone in your backbone is a vertebra (VER-tuh-bruh). The lower bones are fused together. The vertebrae protect the spinal cord inside your backbone. At the side, you see an end view of one vertebra.

1.

2.

ANIMALS WITH BACKBONES

1. **Fishes** live in water, breathe underwater, are covered with scales, and have air bladders and fins.
2. **Amphibians** breathe by means of gills when young and lungs when adult; they live in water when young and on land when adult.
3. **Reptiles** breathe with lungs; most of them have scaly skin.
4. **Birds** are animals whose bodies are covered with feathers, whose feet are covered with scaly skin, and who lay eggs with hard shells.
5. **Mammals** breathe with lungs, have hair covering their bodies, and get milk from their mothers.

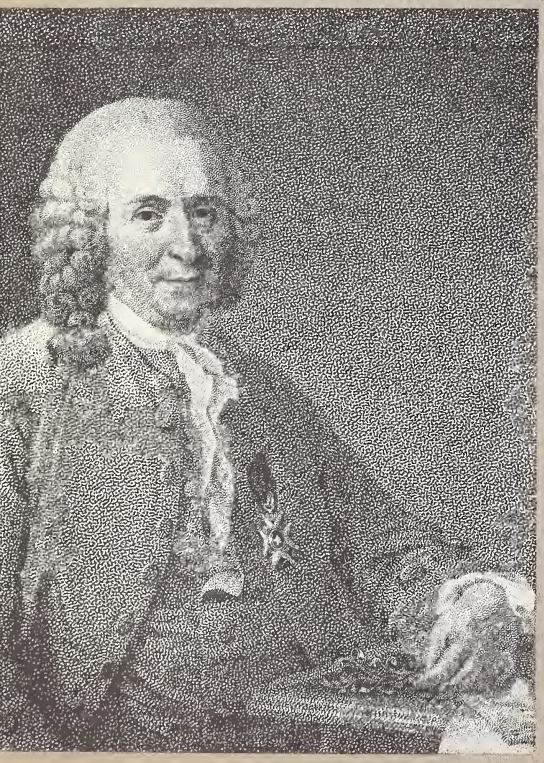
3.

5.

4.

The two groups, *Animals with Backbones* and *Animals without Backbones,* are divided by scientists into smaller groups, which are then divided into even smaller groups.

As you study the pictures, you may be surprised at the way that the scientist groups animals. For example, he puts those animals that have feathers and lay eggs into the bird group. But did you notice that he does not list flying? Yet flying is often what we think of when we think of a bird. Ostriches and penguins are birds, but they do not fly. If we think that an animal must be able to fly to be called a bird, we will make mistakes when we group animals. Not all birds fly—



PATHFINDERS IN SCIENCE

Carolus Linnaeus

(1707–1778) Sweden

For centuries, men tried to explain how living things that looked alike were related. The ancient Greeks, for example, placed all living things on a kind of ladder of life, with man at the top of the ladder and other living things below.

In the 1600's, about 6,000 plants were known. One hundred years later, 12,000 more had been discovered. The great number of discoveries in the 1700's made it necessary to have a system of classification. Such a system was made by Carolus Linnaeus (lih-NAY-uss).

As a young man, Linnaeus collected many different kinds of animals and plants. When he tried to group them, he

but *all birds have feathers,* and *all birds lay eggs.*

It is also true that some animals that fly are not birds. Can you think of any?

Whenever scientists discover a new plant or animal, they compare it with plants and animals they already know about. If the new plant or animal is like those in one of the groups that is already set up, it is put into that group. If it does not seem to belong to any group, a new group may be started.

You now have a good idea of how animals are grouped. Animals that are alike in certain special ways are grouped together. Plants are also grouped in very much the same way.

found very little order in the systems then in use. There was no plan of classification that was widely accepted at that time. There was also no agreement as to what names should be given to each of the living things.

Linnaeus decided to make up a system of classification which would give names to all of the plants and animals. He classified every known animal and plant and gave it a place in his system. He put each of the animals and plants into a special group. Each of the groups had living things in it that were alike in some way.

Although there have been many changes in Linnaeus' system, one part of his plan has remained—his system of *naming* each type of plant and animal. Linnaeus grouped plants that looked alike into a **genus** (JEE-nus). He also grouped animals that looked alike into a genus. For example, the genus that includes the house cat and other cats like it is called *Felis.* Next, Linnaeus made up a **species** (SPEE-sheez) name. The species name for house cat is *domesticus.*

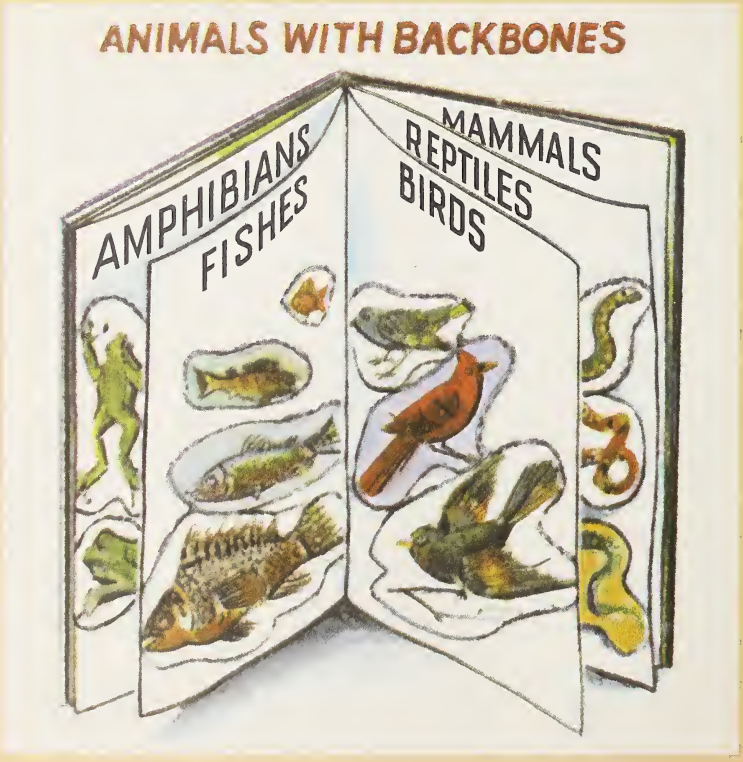
Each living thing has a scientific name made from a genus name followed by the name of the species. The house cat is *Felis domesticus,* the lion is *Felis leo,* the leopard is *Felis pardus.* Can you tell the common name of *Felis tigris?*

Linnaeus' system is known as the **binomial** system (by-NOH-mee-ul). Binomial means "two names." Linnaeus used Latin for his system of classification, because in his time Latin was understood by scientists of all countries.

The work of Carolus Linnaeus has been a guide to scientists for almost two hundred years.

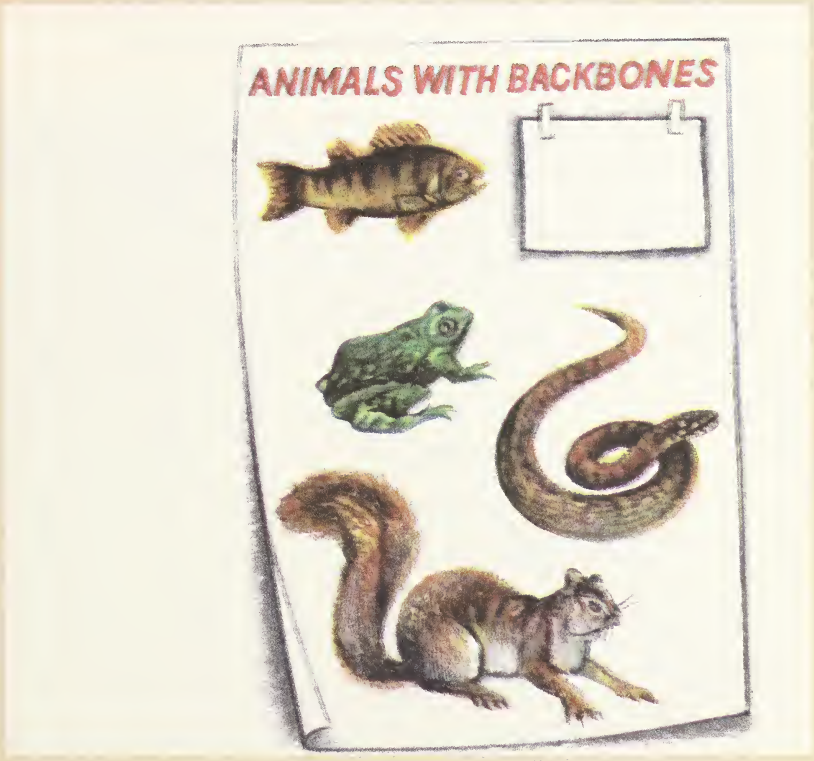
Using What You Have Learned

1. Make a scrapbook of animals. Everyone in the class can bring in pictures of animals. Have a separate section for each of the five main groups of animals with backbones. Find a picture of an animal in each group and write a short paragraph telling something interesting about the animal. Ask your librarian to help you find information. Remember that you should never cut pictures out of library books. Always ask permission before you cut a picture out of a book or magazine.



2. You can take a trip to the public library. Ask the librarian to show you where you can find books about animals, books about plants, and books about famous people. How does the librarian decide where to put each new book?

3. You can make a display in your classroom. Get a large piece of paper and paste pictures of animals from each of the five main groups on it. Now put a flap of paper over each picture. On this flap, write some clues about the animal that is under it. Have some classmates try to guess which animal is under the flap.



WHAT YOU KNOW ABOUT

Animals—Simple and Complex

What You Have Learned

Living things use **oxygen,** use food, give off wastes, and produce more living things like themselves. Each of these activities is called a **life activity.**

Some living things are very simple and others are very complicated. **Biologists** are the scientists who study all living things. They make careful observations and **comparisons.** They have found out that there are certain ways in which all living things are alike. All living things are made of **cells.**

Scientists divide living things into two big groups—*plants* and *animals.* Then they divide these two big groups into smaller groups. The animal group is divided into two smaller groups. One of the groups is called *animals with backbones.* The other group is called *animals without backbones.*

This way of sorting living things into groups is called **a system of classification.**

Checklist of Science Words

Here are some science words you read about in this unit. Can you tell what you have learned about each one?

ameba	connective cells	muscle cells
biology	euglena	nerve cells
cells	hydra	survey
chrysamoeba	life activities	tentacles

What Is the Answer?

Write the numbers 1 to 5 in your notebook. Next to each number, write the answer to that question.

1. What four life activities do living things carry on?
2. What kind of cells support, or hold together, other cells?
3. Are there more animals or more birds in the world?
4. Are there more birds or more ducks in the world?
5. What are the five main groups of animals with backbones?

What's Wrong?

Look at the groups of pictures below. In each group, there is one picture that does not belong with the others. Tell which picture it is and why it does not belong.

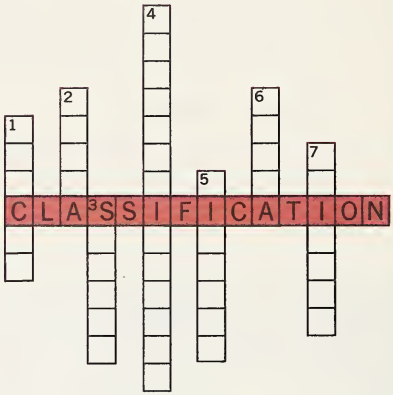
YOU CAN LEARN MORE ABOUT

Animals—Simple and Complex

What Are the Words?

Write the words in your notebook.

1. What kind of cell helps us to move?
2. What is a simple one-celled animal?
3. What are we making when we look for something and keep a record of what we find?
4. What do we call these things: using oxygen, using food, and getting rid of wastes?
5. What is the study of living things called?
6. What is a simple many-celled animal?
7. What is a complicated many-celled animal?



You Can Visit

If there is a zoo near your school, perhaps your class can visit it. When you are at the zoo, you can make a survey of the animals. Tell whether the animals are fish, amphibians, reptiles, birds, or mammals.

Try to find out which is the biggest animal in the zoo and which is the smallest animal.

Are the cages of the animals different? Do all the animals live in cages? Why not?

What has been done to make the living conditions right for the different kinds of animals? Think of heat, light, water, space, and food.

Your class can write a report about its trip to the zoo.

Who Am I?

If you guess on the first clue, you get 3 points; on the second clue, 2 points; on the third clue, 1 point.

1. I live in the water, but I breathe in air.
2. I am the biggest animal that lives in the ocean.
3. I am not a fish.

1. I cannot fly, but I am a bird.
2. I look as though I am wearing a man's suit.
3. I live near the North and the South Poles.

Now make up your own "Who am I?" questions.

You Can Read

1. *The Book of Reptiles and Amphibians* by Michael H. Bevans. Shows different kinds of animals.
2. *All About Birds* by Robert S. Lemmon. Many life stories of birds are told.
3. *Naming Living Things* by Sarah R. Riedman. How plants and animals are classified, and who classified them.
4. *The First Book of Mammals* by Margaret Williamson. Good description of many mammals.
5. *Exploring the Animal Kingdom* by Millicent E. Selsam. You will learn about animal classification.

Do You Remember?

Making *comparisions* is one way in which the scientist finds out more about the world around him. To make accurate comparisons, he uses special *instruments.*

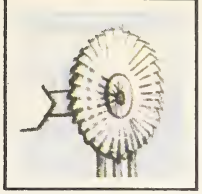
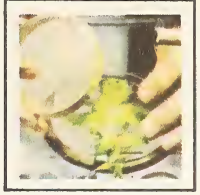
Galileo was one of the first scientists to observe, measure, time, and weigh things to find the answers to his questions. He kept records of all his work and compared his records after doing his *experiments* many times, to be sure of his results.

In an experiment, the things which the scientist keeps the same are called *controls.* The one thing that he changes is called the *experimental factor.* There should never be more than one experimental factor.

By doing experiments, scientists have found out a great deal about *energy.* Energy means the ability to do *work. Light, electricity, sound,* and *heat* are four kinds of energy. Energy can change its form. Heat energy can be changed into *mechanical energy. Stored energy* can become *energy in action.* Using a *force* takes energy. A force is a push or a pull on an object. When forces move an object, work is done and energy is used. We often use *simple machines* like *pulleys* and *levers* to help us move objects.

Gravity is one of the most important forces that start things moving. Gravity pulls things toward the earth. *Friction* is a force that makes things stop. When two things move against each other, there is friction.

Plants with *chlorophyll* use the light energy from sunlight to make food from water and *carbon dioxide.* The food that green plants make is a sugar called *glucose.* This process is

called *photosynthesis*. Glucose and the foods made from it have energy from sunlight stored in them.

Carbon dioxide enters green plants through tiny openings in the *leaves*. Water and minerals are absorbed through the root hairs on the *roots* and are carried through the *stem* to other parts of the plant. Plants store food in roots, stems, seeds, and *bulbs*.

Living things need energy to carry on their *life activities*. This energy comes from the burning of food within the living thing. The food for animals comes from green plants or from other animals that have eaten green plants. Everything you do takes energy which can be traced back to the sun.

Some living things are very *simple* and others are very *complicated*. But all living things are alike in certain ways. All living things use *oxygen*, use food, give off wastes, and produce more living things like themselves.

Scientists have a *system of classification* which places all living things into groups. The two big groups of living things are plants and animals. The animal classification is then broken down into *animals with backbones* and *animals without backbones*. Fishes, amphibians, reptiles, birds, and mammals are animals with backbones.

In this section of your science book, you have found out what energy is, how it is captured by green plants, and how it is used by living things. In the next section, you will learn about some of the forms of energy and how these forms are used by man.

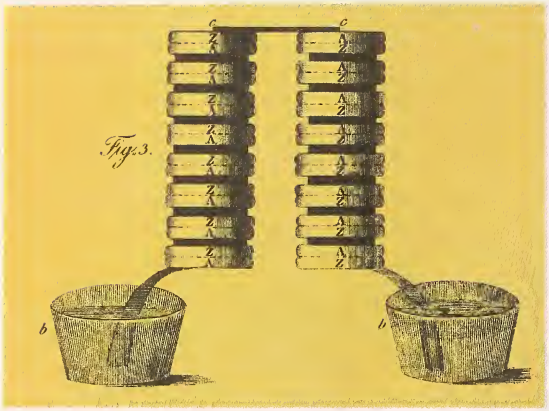


Fig. 3.
c
c
b
b

5

Using Electricity

Electricity and the Atom

Different Kinds of Electricity

Electricity to Do Work

Every time you turn on a radio, or switch on a lamp, or use a toaster, you are using electrical energy. You use this form of energy to do all kinds of work. How many things in your house need to be plugged into an electrical outlet? Can you make up a list of things in your house that are run by electrical energy?

Electricity and the Atom

Electricity can be used to make things move, stop, and turn. Electricity is a form of energy. It can be used to run refrigerators and air conditioners, which make things cool. It can be used in kitchen ranges to make things hot, and in electric bulbs to give us light.

Electricity can do many things that are useful to us. Scientists, however, have another reason for being interested in electricity. In learning more about electricity, scientists understand more and more about the world around us.

When you hear the word *electricity,* you probably think about electric outlets and plugs, or batteries and wires. But have you ever heard thunder-and-lightning storms called "electrical storms"? And have you ever received an "electrical shock" when you walked across a rug and touched a door handle? You know, then, that there can be electricity even when there are no electric outlets and plugs, or batteries and wires.

To understand more about electricity, you must know something about the way scientists think of everything that fills space. **Matter** is the name that scientists give to things that fill space. Solids, gases, and liquids fill space. Mountains and rivers, trees and air, elephants and fleas all fill space, and they are all called matter. All matter—solid, liquid, and gas—has weight. **Physics** (FIZ-ikss) is the science that studies matter. **Physicists,** the scientists who study matter, believe that all matter is electrical.

Look carefully at the picture. How many things do you see that are run by electricity? Are things run by batteries also electrical? How can you tell?

Scientists believe that all matter is made up of **atoms**. Solids, gases, and liquids, mountains and rivers are all made up of atoms. Atoms are very, very small. They are so small that it would take a billion billion of them to fill a pinhole in this page. That is a bigger number than any of us can imagine.

Electrons and Protons

As small as atoms are, they are made up of even smaller parts, or particles. These are called **electrons** (ih-LEK-tronz), **protons** (PROH-tonz), and **neutrons** (NOO-tronz). Right now you will learn more about electrons and protons as you read on. In later grades, you will learn about neutrons.

These are atoms. On the left, one electron moves around one proton. In the center, two electrons move around two protons and two neutrons. On the right, eight electrons move around eight protons and eight neutrons. What is the same about them all?

From the word *electron,* you might guess that there is something electrical about this tiny particle. There is. Scientists have discovered that every one of the small electrons has an electric charge. Every proton also has an electric charge. This means that each one of these particles puts forth its own electrical force. The force of these particles may be a *push* or a *pull.* The electrical charge of each one is very small, and so the force is small.

Two Kinds of Charges

Scientists have also discovered that these protons and electrons have different charges. Each proton has a **positive charge.** Scientists use the sign + to show the proton's positive charge. Each electron has a **negative charge.** Scientists use the sign — to show the electron's negative charge.

An atom has the same number of protons and electrons. But an atom can *lose* some electrons. Then it is left with more *protons* than electrons. The atom then has a positive charge. An atom can also *gain* electrons. If an atom gains some extra electrons, it has a greater number of negative charges. The atom then has a negative charge.

What happens to the combs in the first part of the experiment on page 143? Describe the way they act.

How Do We Know There Are Two Kinds of Charges?

What You Will Need

2 plastic combs
piece of fur
glass rod
piece of silk

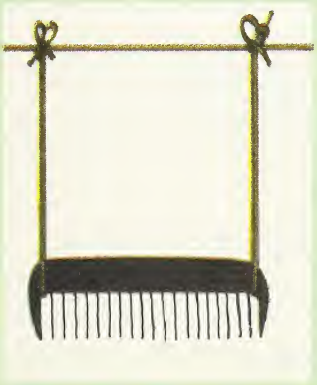
How You Can Find Out

Part I

1. Make a little swing on which you can rest one of the combs.
2. Rub each comb with a piece of fur.
3. Put one comb on the swing and bring the other comb close to it.

Part II

1. Rub the glass rod with the piece of silk.
2. Bring the rod near the comb on the swing that you rubbed with fur.



Questions to Think About

1. What happens when you bring the combs together?
2. What happens when you bring the glass rod near the comb?

Things that are electrified do not always push away from each other. In the second part of the experiment on page 143, the glass rod and the comb pulled toward each other. The "push" or "pull" of the combs and of the rod was caused by the electric charge of the atoms in the combs and in the rod.

From these experiments, you can see that an atom can act in two ways. It can pull toward another atom or it can push away from another atom.

If the two atoms have different charges, they will pull toward each other. What do you think happens when two atoms with positive charges are brought together? What do you think happens when two atoms with negative charges are brought together?

Look at the picture of atoms on page 142. Protons are in the center of each atom and have a positive charge. Electrons circle around each center and have a negative charge. Electrons are in **orbit.**

Electrons do not always stay in orbit. For example, when you rubbed the glass rod with silk, some of the electrons of the rod went over to the silk. The rod lost some of its negative charge and became positive.

How Like Charges Act

You remember that the two plastic combs received extra electrons when they were rubbed with fur. Both combs then had a negative charge. When the two combs were brought together, they pushed away from each other because both had the same kind of charge. But why did the rod and comb pull toward each other when they were brought together?

What happens if two things with positive charges are brought together? To find out, do the experiment on page 145.

If two objects both lose electrons, each is left with more protons. Each then has a positive charge. The objects push away from each other. *When any objects have the same kind of charge, they will push away from each other.*

How Unlike Charges Act

You now know what happens when the charges are both the same. What happens when the charges are different? Try giving a plastic comb a *negative* charge (rub it with fur so that it gains extra electrons). Then give a glass rod a *positive* charge (rub it with silk so that it loses electrons). The plastic

What Happens When Things Have Like Charges?

What You Will Need

2 glass rods piece of silk

How You Can Find Out

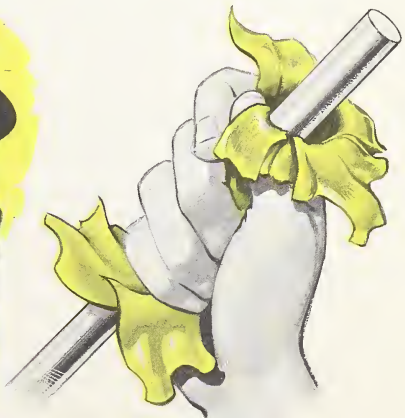
1. Hang one of the glass rods on the back of a chair with a piece of string.
2. Rub each of the rods with the piece of silk. (The glass does not hold its electrons tightly. Both rods will lose electrons. Now the rods have more protons than electrons.)

Questions to Think About

1. What happens when you bring the second glass rod near the first one?
2. Explain what happened in terms of + and − charges.

comb and the glass rod will pull toward each other. *Objects with different charges pull toward each other.*

Try rubbing a balloon on wool. The balloon will get some extra electrons. It will become negatively charged. But where do these extra electrons come from? The wool gives them up. The wool loses electrons and becomes positively charged. Now the balloon and the wool have charges that are not alike. Let the balloon rest on the wool where you have been rubbing. Take your hand away. What happens?



The balloon, with the — charge, and the wool, with the + charge, stick together. Two objects with different charges attract each other.

Shortly, the balloon falls from the wool to the floor. The balloon and the wool are no longer pulled toward each other. The extra electrons have left the balloon and gone back to the wool. The balloon and wool now have their usual number of electrons. When electrons and protons are in balance, objects are not pulled toward or pushed away from each other.

EXPERIMENT

Does Distance Affect the Pull Between Two Objects?

What You Will Need

2 balloons
piece of wool
2 glass rods
piece of silk

How You Can Find Out

1. Rub two balloons with wool.
2. Place the balloons far apart on the table.
3. Bring the balloons closer together.
4. Next, rub the glass rods with silk. First hold them far apart. Then, slowly move them toward each other.

Questions to Think About

1. What happens when the balloons are far apart?
2. What happens when the balloons are close together?
3. What happens when you hold the rods far apart?
4. What happens when you bring the rods closer together?

Distance Makes a Difference

You have already read that when charges are not the same, objects are pulled toward each other. The closer the two objects are, the more they are pulled together. You saw this happen in the activity on page 146.

To remember what you have learned, think of the following summary. *The farther apart the charged objects are, the less they will pull toward each other. The closer the unlike objects get to each other, the more they will pull toward each other.*

Using What You Have Learned

1. You can bend a stream of water. Open a faucet so that just a thin stream of water comes out. Rub a comb with fur, nylon, or wool. Hold the comb near the stream of water.

   What happens? Why?

2. Press the toe of a nylon stocking against the wall. Rub the stocking with a clear plastic bag. Hold the stocking in the air and you will see it fill out as if someone's leg were in it.

   Can you tell why this happens?

3. You can make pieces of paper dance. Put a piece of glass on two books. From a sheet of writing paper, cut out pieces of paper about ½″ long and ½″ wide, and put them under the piece of glass. Now rub the glass with a piece of nylon or silk.

   What happens to the pieces of paper? Why do you think this happens?

Different Kinds of Electricity

Now that you know something about the way electrons move, you can learn about the different kinds of electricity.

Static Electricity

When you make electrons move from one object to another you are making a kind of electricity. One kind of electricity is called **static electricity.** Static electricity is the kind made whenever two objects are rubbed together. The friction makes electrons go from one object to another. Static electricity is not very useful to us. It will not run motors or light lamps.

Although static electricity is not useful to us, we sometimes feel its effects. When you walk across a wool rug in the wintertime and touch another person, you sometimes get a small electric shock. Electrons from the wool rug rub off on you, and you then get a small charge of static electricity.

When you comb your hair on dry winter days, your hair sometimes seems to crackle and stick to the comb. Some of the electrons of your hair have rubbed off on the comb, giving it a — charge of static electricity. What kind of charge does your hair have after it is combed?

Current Electricity

The kind of electricity that we use to help us with our work, or light our way, or heat our houses, is called **current electricity.**

Current electricity is different from static electricity. In static electricity, friction makes electrons go from one object to another. When the electrons get to the second object, they remain at rest. But in current electricity, a continuous flow of electrons enters an object, travels through it, and then passes out of it.

Some materials make good paths for flowing electrons. These materials are called **conductors** (kun-DUK-terz). A copper wire is a good conductor.

In each atom of copper, there is one loose electron which can become free. The word "free" simply means that the electron can be pushed out of its usual orbit in the atom. When this happens, the electron is no longer attached to its atom. The electron is free to move about by itself.

Loose electrons cannot leave their atoms unless something pushes them. One way to start loose electrons moving along a wire is to use a **dry cell** to push

These materials are all conductors. What part of each is the conducting material? How are you able to tell?

them. On page 154, you will learn more about how a dry cell works. As you will see, there are materials in the dry cell which release free electrons of their own. When a copper wire is attached to a dry cell, the free electrons of the cell start pushing upon the loose electrons in the copper atoms of the wire. Millions of loose electrons from the copper atoms in the wire are pushed until they become free also. The dry cell pushes all the free electrons in the same direction.

Current electricity is really the continuous flow of free electrons. These electrons are all pushed along a path.

An electric current can flow easily through most kinds of metal. This is because most metals have loose electrons in their atoms, which can become free if they are pushed. That is why most metals are good conductors.

Materials that do not allow electrons to move easily are not good conductors. They are called **insulators** (IN-suh-lay-terz). Thread, rubber, and glass are insulators.

Using Current Electricity

A scientist named Alessandro Volta (ah-leh-SAHN-droh VOHL-tah), who lived from 1745 to 1827, made the first electric cell. You can make an electric cell something like Volta's.

In the next experiment, you will find that when silver (dimes) and copper (pennies) are placed in salt water, electrons leave the silver and move to the copper. Other metals can be used to make an electric cell.

These materials are all insulators. What part of each is the insulating material? How are you able to tell?

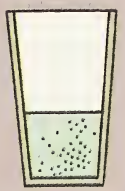
How Can You Make an Electric Cell?

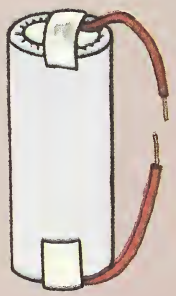
What You Will Need

8 clean pennies	paper tubes for pennies	pair of scissors
8 clean dimes	blotting paper	cellophane tape
sandpaper	glass of salt water	2 six-inch wires

How You Can Find Out

1. Sandpaper all of the coins lightly to make them clean.
2. Put eight pieces of blotting paper, each about the size of a dime, into the glass of salt water to soak.
3. Make a sandwich of pennies, dimes, and soaked blotting paper in your paper tube. Stack them in this order: penny, blotting paper, dime.
4. Cut the paper tube off at the last dime on top.
5. With the cellophane tape, fasten one of the short wires against the bottom penny and the second wire against the top dime.
6. Touch the other ends of the two wires to your tongue.





Questions to Think About

1. What happens when you touch the wires to your tongue?
2. What is the name given to this kind of electricity?

PATHFINDERS IN SCIENCE

Alessandro Volta

(1745–1827) Italy

One day in 1786, an Italian biologist named Luigi Galvani was dissecting a frog in his laboratory. His knife touched a nerve in the dead frog's leg. The leg jumped. Galvani tried to find out why this happened.

Galvani reasoned that all animals, whether they are dead or alive, have electricity in them. He reasoned that electricity was made when he touched the frog's leg with his knife.

However, another Italian scientist, Alessandro Volta, thought differently. Volta tried to repeat what had happened in Galvani's experiment, but instead of using a frog, he used himself. He placed a piece of tin on top of his tongue and a

The work of Galvani, a scientist, interested Volta in finding out how electricity is made. After many experiments Volta was able to demonstrate how electricity is produced.

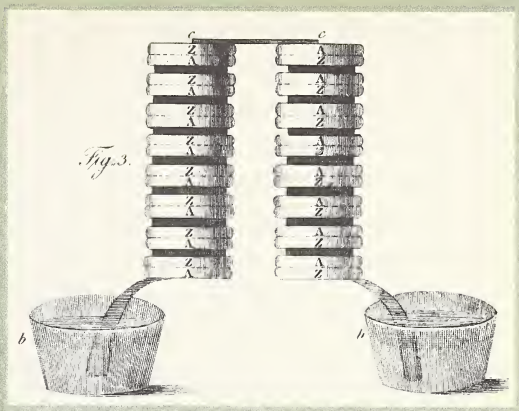
silver coin under his tongue. Then he let a copper wire touch both pieces of metal at the same time. When he did this, he got a sour taste in his mouth. The taste lasted only as long as the tin and silver were connected by the copper wire. This showed that there was a flow of electricity from one place to another.

Volta repeated the experiment, but this time he used a piece of cardboard soaked in salt water instead of using his tongue. Again, an electrical current was made.

From these and other experiments like it, Volta reasoned that the metals not only acted as conductors of electricity, but were actually making their own electricity.

How does all this explain why the frog's leg had jerked when Galvani was dissecting it? Volta said that Galvani's knife was made of one kind of metal, and the box which held the frog was made of another. The frog acted in the same way as the piece of soaked cardboard. It allowed an electrical current to be made. Without knowing it, Galvani had used the right metals and the correct ways to set up an electrical current. When the two different types of metals were in contact, enough electricity was made to cause the frog's leg to jump.

Volta reasoned that if *two* pieces of different metals and a soaked piece of cardboard could produce a little electricity, then *many* pieces of metal and soaked cardboard would produce a great deal more electricity. After many experiments, Volta built the "pile," which was the first electric battery.



Volta's own drawing shows how he set up a series of silver and zinc discs, separated by brine-soaked paper, for his experiments.

Volta had discovered how to use chemicals to create a mild but steady flow of electric current. His discovery made it possible for electric current to be supplied for many of man's needs. His invention opened the way for other scientists to invent the telegraph, the telephone, the radio, and thousands of other machines.

The word "volt," which is a unit of measurement in electricity, is now used by scientists to honor Volta's work.

Dry Cells of Different Sizes

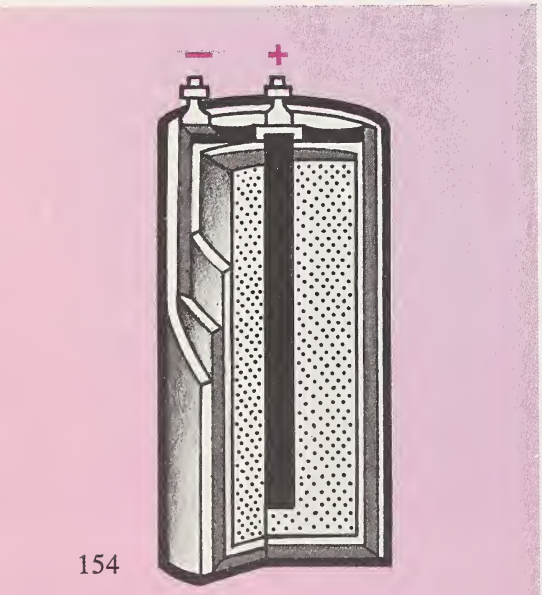
Here are three different sizes of electric cells called *dry cells*. Do you know what is inside each one?

First find a used dry cell. The large size will be easier for you to open and to see. Open it carefully. You may need help from the school custodian.

The inside of the dry cell is filled with a paste-like material. There is a solid black rod in the middle. The metal, the paste-like material, and the solid rod act like the pennies, dimes, and salt water that you used to make electricity.

Why must the bulb be connected as shown?

A section through a dry cell.



The dry cells in the picture are of different sizes. Which do you think will make the brightest light? To find out, get three dry cells like the ones in the picture. Connect each of the dry cells to a small flashlight bulb as you see in the picture. What happens?

Electricity from the larger dry cell does not make the bulb any brighter than electricity from the smaller dry cell. Each of these cells produces the same amount of energy. But the larger cell will give off energy for a longer time than the smaller one. Why?

The amount of push behind the electrons in these dry cells is very small. You know it is not enough to shock you. In the electricity in your home, the amount of push on the electrons is 80 times greater. It can knock you over or even kill you. That is why we must use electricity in our homes and schools with great care.

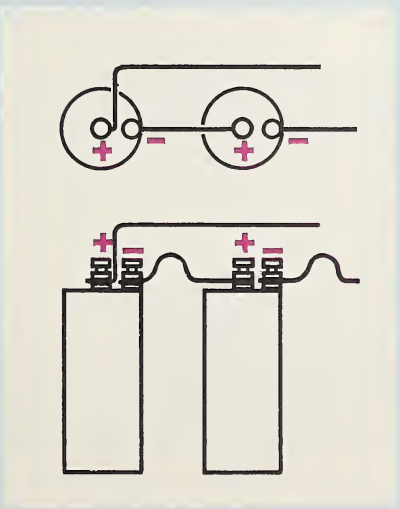
Using More Than One Dry Cell

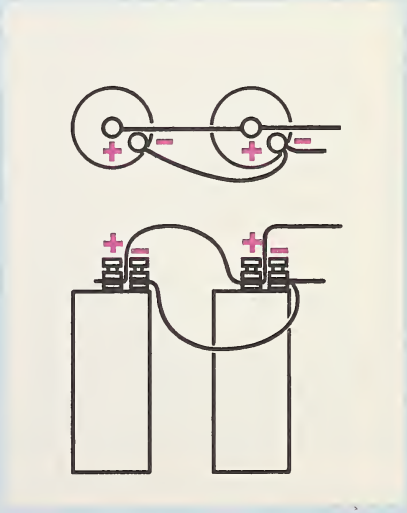
Do you increase the amount of push upon the electrons when you use two dry cells? If you connect two cells, as you see in the picture, the flow of free electrons will move twice as fast as when you use only one cell. The lamp will burn more brightly, then, but the cells will be used up more quickly than if only one cell were used at a time.

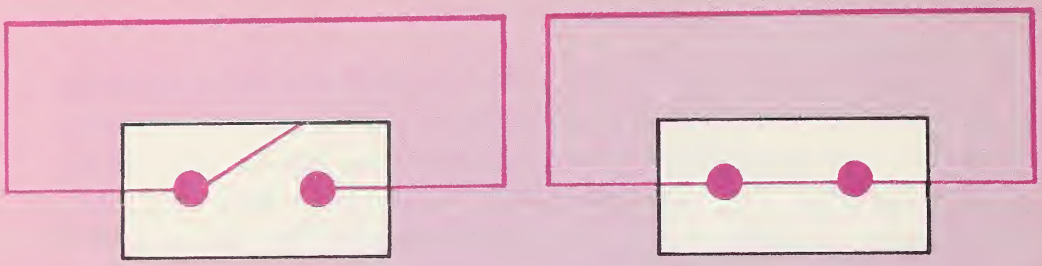
When two dry cells are connected as in the picture below, the electrons have only as much push as one of the dry cells. Your lamp will not burn as brightly as when you connected the cells before. But your dry cells will keep the lamp burning twice as long.

To light several lamps, you should use two dry cells to get twice as much push. How would you connect them?

Tell what happens if you connect the cells as shown in the pictures below.







Which of these pictures shows an open circuit? Which shows a closed circuit? Through which will electric current flow? How can you be certain of your answers?

Open and Closed Circuits

Remember, electrons must move through something after they leave the dry cell. The path through which they move is called a **circuit** (SER-kit). The circuit must begin and end at the dry cell.

A circuit that has no openings in it is called a **closed circuit.**

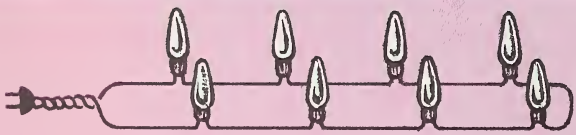
When the circuit has an opening in it, it is called an **open circuit.** When the circuit is open, the current will not flow through.

Look at the picture below. If you take one of the bulbs out of its socket, what happens? Can you tell why? What has happened in the circuit? Where did it happen? This kind of circuit is called a **series circuit.** Can you tell why?

Now connect the lamps as in the picture below. Take out one of the lamps. What happens? Trace the circuit and you will see that it is still closed. That is why the other lamps will still burn. This kind of circuit is called a **parallel circuit.** Can you tell why?

How are Christmas tree lights connected? Have you seen other strings of lights? How are they connected? Why are they connected that way?

What kind of circuit does each picture show? How are you able to tell? Tell where each kind of circuit is used and why it is used in the type of situation you name.

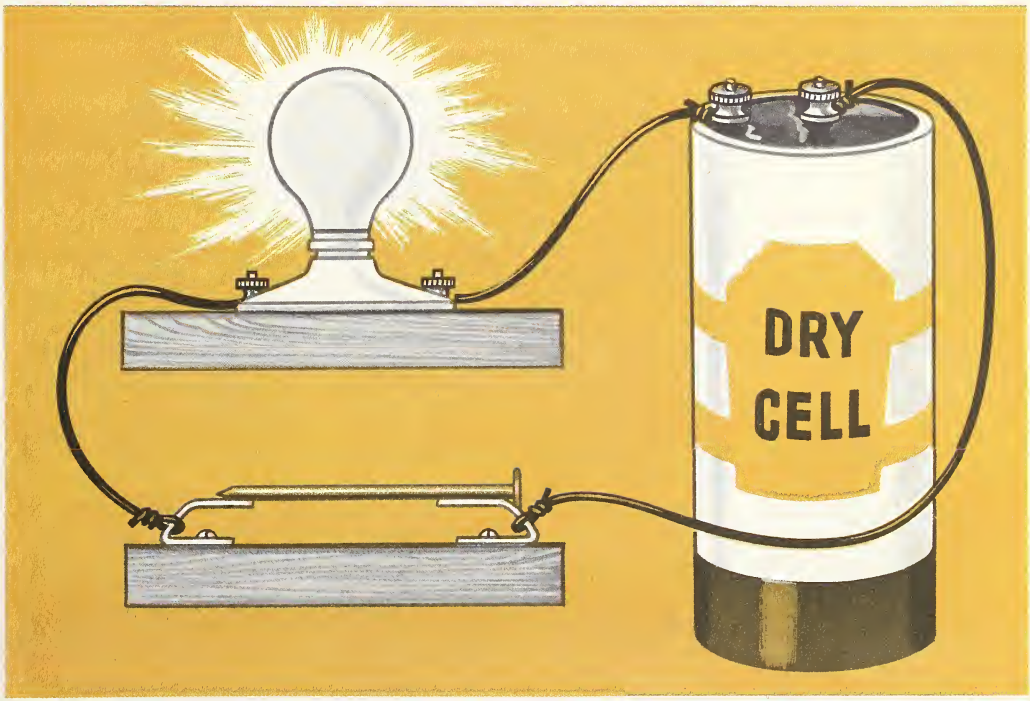


Using What You Have Learned

1. Here is a way to find out if something is a good conductor of electricity.

Bend two metal pieces in half and punch holes in them for screws. Screw the pieces of metal to a wooden block about 2 inches apart. Now connect the dry cell in the way that is shown in the drawing.

You now have a complete circuit except for the space between the metal pieces. If a conductor is laid across this space, the light will go on. If an insulator is laid across the space, the light will not go on. Try different kinds of materials to see if they will conduct electricity.



2. What other kinds of electric cells are there besides dry cells? How are they different from dry cells?
3. You can make your own flashlight. You will need two flashlight dry cells, a piece of paper that is long enough to cover them, bell wire, and a flashlight bulb. Wrap one end of a piece of bell wire around a flashlight bulb. Place the cells and wire as you see them in the picture.

   Now roll the dry cells and the wire in the paper, and put two rubber bands around the roll. Also, put a rubber band around the long part of the roll to make sure both dry cells stay together and touch each other.

   To make the flashlight work, you touch the loose end of the wire to the bottom cell, and the bottom of the flashlight bulb to the top of the other cell, as shown in the picture.

Electricity to Do Work

We use some electricity in our homes to heat things, such as toasters and irons. But this is not using electricity to do *work*. You have learned on page 29 that work is done when a force moves an object. How can we use electricity to do work for us? We do this by using **electromagnets** (ih-lek-troh-MAG-nits).

An electromagnet is a piece of metal with a coil of wire around it, which becomes a magnet when an electric current flows through the coil.

Electromagnets

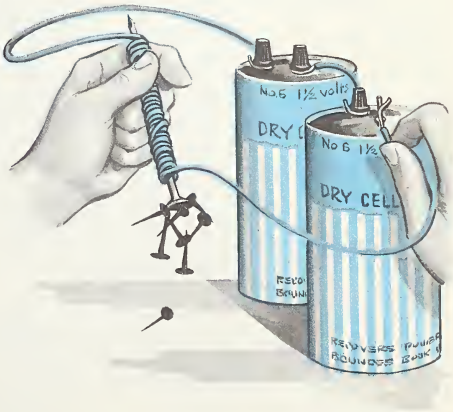
Electromagnets can do all of the things other magnets do. We can use them more easily because they can be turned on and off. Let's see how to make an electromagnet.

You can make a nail into an electromagnet by winding wire around a nail as you see in the picture. Connect only one end of the wire to a dry cell. Now touch the other end to the dry cell. You will have an electromagnet. Never leave both wires connected to a dry cell. Can you tell why?

There are two ways in which you can make an electromagnet stronger. One way is to increase the push on the electrons in a circuit. This will force more electrons through the circuit.

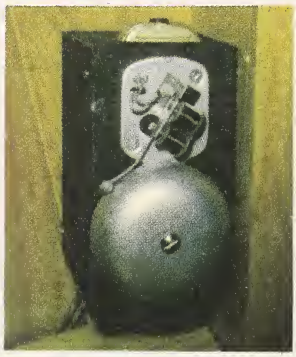
Try this. Use one dry cell to make an electromagnet, and test it to see how many nails it will pick up. Then connect two dry cells as you see in the picture. How many nails can you pick up now? Put a rubber band around the nails to hold them together.

Try making electromagnets as shown in the pictures below. What differences occur?



You have just shown how increasing the push on electrons will make your electromagnet stronger. The other way to make it stronger is to put more coils of wire around the nail. First test your electromagnet with only a few coils of wire. See how large a bundle of nails it will pick up. Now try your electromagnet with more coils. It will pick up a larger bundle of nails.

Many things that we use in the home to do work have electromagnets in them—electric fans, washing machines, and others. The part that does the work in each of these machines is the motor. There are a number of electromagnets in each motor. The electromagnets make a wheel turn inside the motor. When the wheel turns, it can be made to turn other things.



These two pictures show electromagnets. Can you tell which is the electromagnet part of each and what kind of work it does?

Each year many fires occur needlessly because houses are not properly wired. Wires either are too thin to carry the flow of current or are not protected by insulation. Wires carrying electric current must be covered with material that will not conduct electricity. Rubber is an insulating material commonly used on wires. When the insulation on a wire is broken, the unprotected wires may cause a fire. Can you tell how?

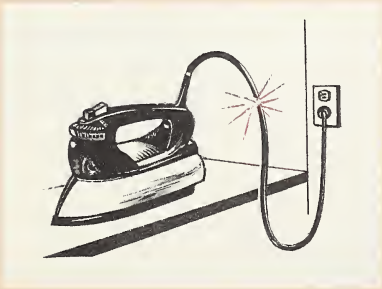
When the insulation around a wire is broken or frayed and the bare wire is touched, there is great danger of injury. Electric current might go through a person's body instead of through the wire. A good rule is never to touch a frayed wire unless the plug is first removed from the wall outlet.

Sometimes electric cords become broken and the bare wires touch each other. When this happens, there is a **short circuit.** Look at the picture below. Can you tell what happens to the electrons moving through the wires when there is a short circuit?

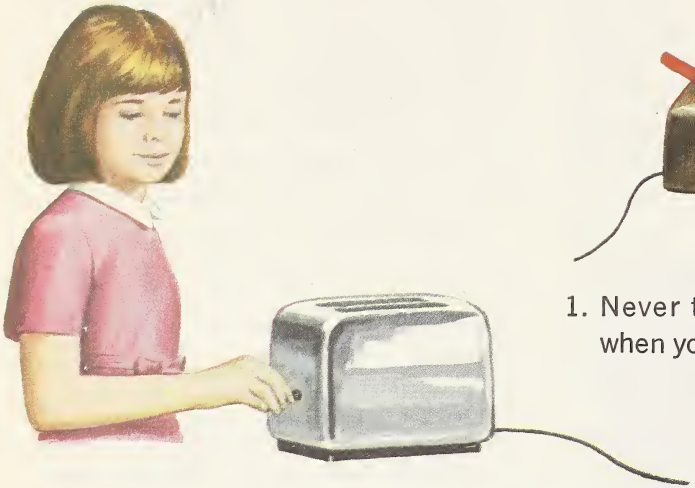
When too many appliances are used on one circuit, the circuit becomes overloaded with moving electrons. The wires become hot. What is the danger when this happens?

On the next two pages you will find rules to follow that will help you to use electricity safely.

What has happened to the wire on the iron below? What might this condition cause? What do you see happening in the picture on the right? How can this be corrected?

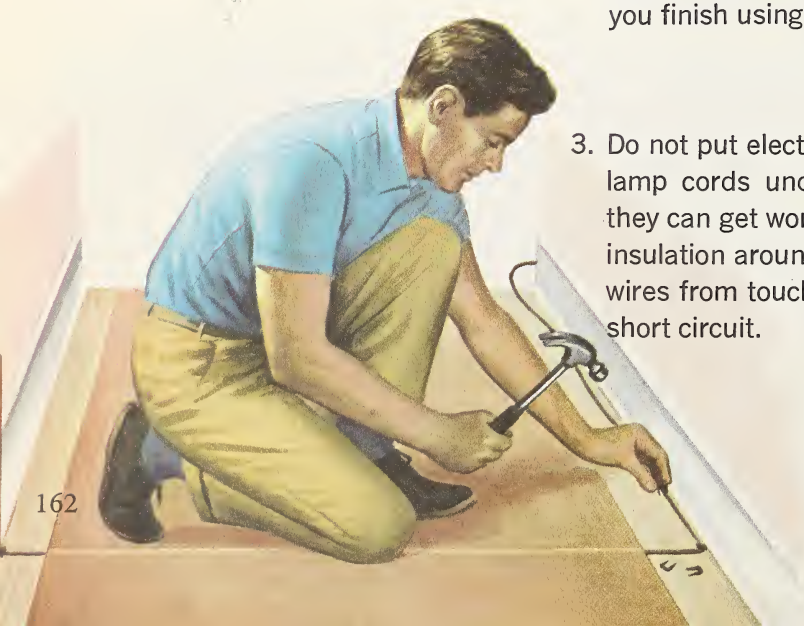


USING ELECTRICITY SAFELY



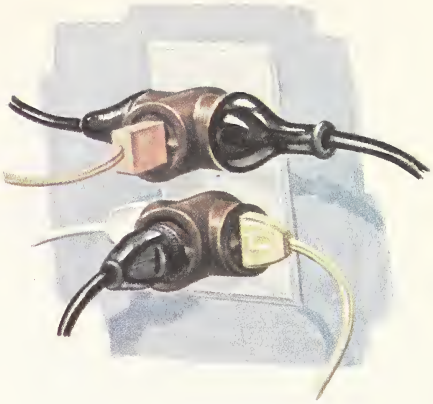
1. Never touch anything electrical when your hands are wet.

2. Turn off irons, heaters, toasters, and other electrical things when you finish using them.



3. Do not put electrical cords such as lamp cords under rugs or where they can get worn. Remember that insulation around a cord keeps the wires from touching and causing a short circuit.

4. Do not plug too many electrical wires into one outlet. This overloads and heats the wires and can start a fire.



5. Never poke your fingers or any object into electric outlets or sockets.

6. Never touch wires that have fallen down outdoors. Tell a grownup about the wires. He can call the police department and the power company. They will know how to repair the wires.

How Fuses Protect

A **fuse** protects your house from fires by opening the circuit when too many electrons are moving through the circuit. The metal in a fuse melts before the wires get too hot. This action opens a gap that stops the flow of electricity, so that fires cannot start.

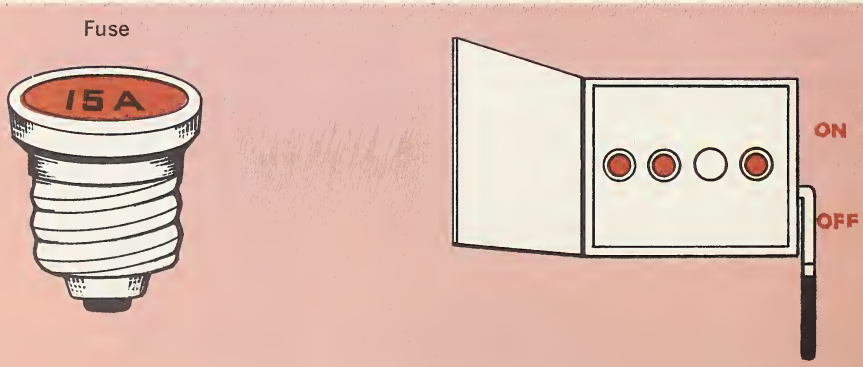
Sometimes people close the circuit by putting a penny in the fuse socket after the fuse blows, instead of using a new fuse. This is dangerous, and no one should ever do it. A penny will not melt easily. The penny allows the electrons to continue moving through a circuit, and the wires may get hot enough to start a fire. Before anyone puts in a new fuse, he should find out what made the old one burn out.

The person who changes a fuse should always open the main switch first, near the fuse box. This shuts off the electric current in the whole house. It is then safe to change the fuse.

Whoever changes the fuse should be sure the new fuse has the same number as the old one had, such as "15A." A fuse that has a larger number should not be used. It should not be used because it will allow too many free electrons to go through the wires of the circuit. If the wires are overloaded, they may become so hot that they will melt and start a fire.

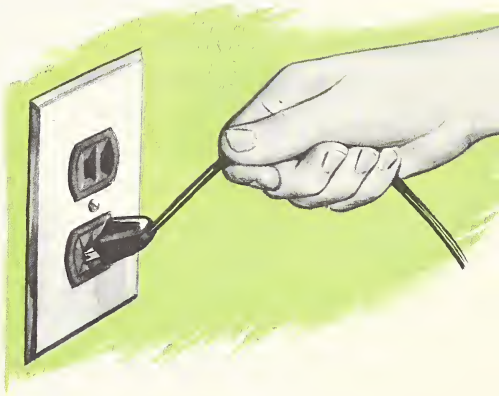
Electricity in your house is safe to use, *if you use it wisely*. But it can be dangerous if you do not know how to use it.

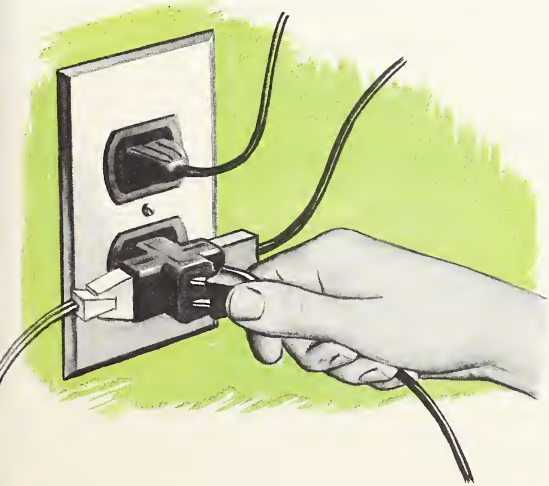
The fuse box in your home may look like the one below, or it may have circuit breakers. If it is like the one below, pull the handle to OFF before replacing the fuse. If you have circuit breakers, switch the breaker back again after finding the cause.



Using What You Have Learned

Look at the pictures below. How many things can you find wrong? Can you tell what safety rules are being broken? How would you correct the things that are wrong?





WHAT YOU KNOW ABOUT

Using Electricity

What You Have Learned

All **matter** is made up of **atoms.** Atoms are made up of **electrons, protons,** and **neutrons.** Every electron and proton carries a charge of electricity. The electron carries a — or **negative charge** and the proton carries a + or **positive charge.** Charges that are alike push away from each other, and charges that are not alike attract each other.

Static electricity is electricity that is at rest on an object. **Current electricity** is electricity caused by electrons moving through an object.

Materials that allow electricity to move easily through them are called **conductors.** Copper is a good conductor. Materials that do not allow electricity to move easily through them are called **insulators.** Rubber is a good example of an insulator.

The path over which current electricity moves is called a **circuit.** A **closed circuit** is one that begins and ends at a dry cell or other source of electrical energy. There are no openings in a closed circuit. A circuit with an opening in it is called an **open circuit.**

Checklist of Science Words

Here are some science words you read about in this unit. Can you tell what you have learned about each one?

atom	electromagnet	matter
circuit	electron	orbit
conductor	fuse	proton
current electricity	insulator	static electricity

Tell the Difference

Write the numbers 1 to 7 in your notebook. Next to each number, write a sentence that tells how the two things in each question are different.

1. How does static electricity differ from current electricity?
2. How does a conductor differ from an insulator?
3. How does a closed circuit differ from an open circuit?
4. How does a proton differ from an electron?
5. How do like charges differ from unlike charges in their ability to attract each other?
6. How does a parallel circuit differ from a series circuit?
7. How does a 15A fuse differ from a 30A fuse?

Find the Answer

Write the numbers 1 to 10 in your notebook. Next to each number, write the word or words that best fit the description below.

1. Something that makes a good path for electrons.
2. Electricity that is at rest on an object.
3. Everything that fills space.
4. Something that does not allow electrons to move easily from atom to atom.
5. Electricity in which electrons move along a path.
6. What all matter is made of.
7. What happens when bare wires touch each other.
8. The charges that make up an atom.
9. Something that opens a circuit when too many electrons move through the circuit.
10. The charge an electron carries.

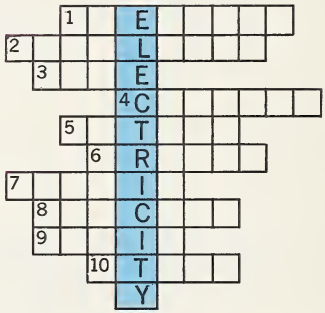
YOU CAN LEARN MORE ABOUT

Using Electricity

What Are the Words?

Write the words in your notebook.

1. The part of the atom that has a − charge.
2. Poor conductor of electricity.
3. Protects your home when electric wires are overloaded or broken.
4. The kind of electricity that lights our houses.
5. Everything that fills space.
6. The part of the atom with a + charge.
7. Electricity which is at rest on an object.
8. A good path for electricity.
9. To circle around something.
10. What all matter is made up of.



You Can Do This

Sprinkle some salt and some pepper on a piece of paper. Ask someone to remove the pepper from the salt—*without touching either one.*

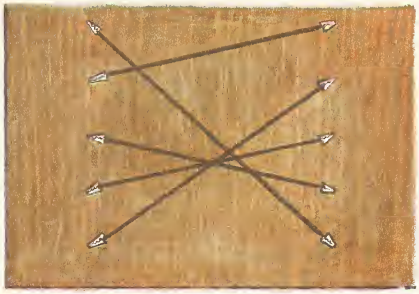
Here is how you do it. Run a comb through your hair a few times. Then hold the comb about an inch above the pepper and salt. Can you explain what happens?

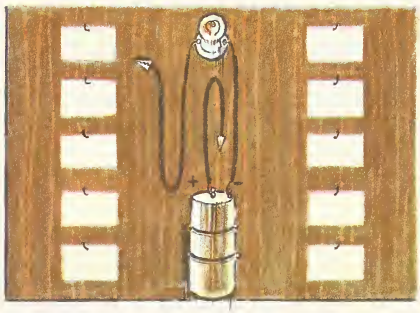
Make an Electrical Questioner

You will need a piece of plywood, 10 cup hooks, 10 pieces of bell wire, 10 alligator clips, a dry cell, and a flashlight bulb.

Screw the cup hooks into the wood in two rows of five each. Remove the insulation from the ends of the wires and attach them to the cup hooks with clips, as you see in picture 1. Attach the dry cell, the bulb, and the wires to the other side of the board, as you see in picture 2.

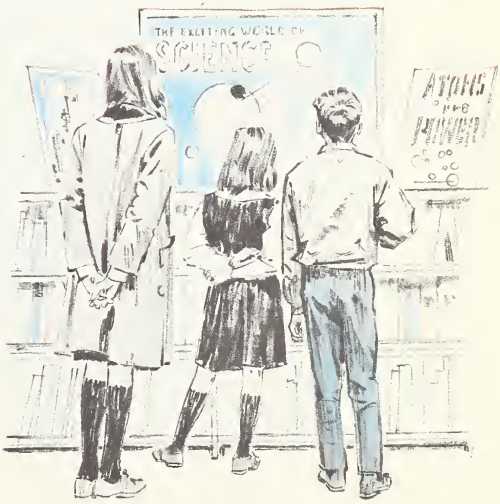
Hang question cards on the first row of hooks and hang the answer cards on the hook to which you attached the wire. If you clip an "answer" hook to the right "question" hook, the bulb will light.





You Can Read

1. *Experiments with Electricity* by Nelson Beeler and Franklyn Branley. Experiments you can do at home.
2. *The First Book of Electricity* by Sam and Beryl Epstein. What electricity is and what it does.
3. *Picture Book of Electricity* by Jerome S. Meyer. Many experiments with electrical phenomena.
4. *A Boy and A Battery* and *Fun with Electrons* by Raymond F. Yates. Both have many experiments.



6

Sound–A Form of Energy

What Is Sound?

What Makes Sounds Different?

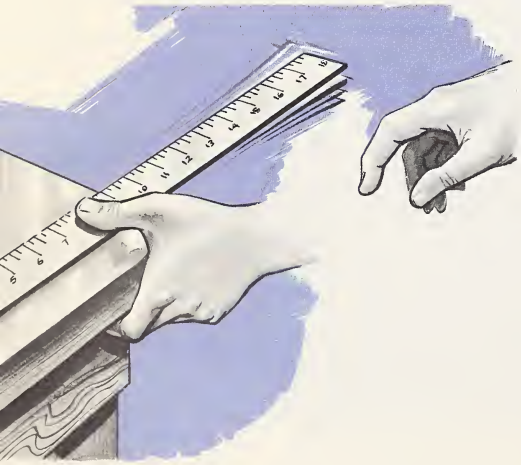
Reflected Sound Waves

You have been finding out about energy and the many forms it takes. Are you surprised to find that sound is a form of energy? You know that energy is being used whenever matter is moved. What does this have to do with sound? Can sound energy get work done? In this unit you will find out.

What Is Sound?

Sound is everywhere. You hear all sorts of sounds. Some you find pleasant. Some you find not so pleasant.

What is sound? Here is an old riddle that is often asked when students try to find out what sound is. "If a tree falls in the middle of a great forest, and nobody is near to hear it fall, will there be a sound?" Before you read farther, what do you think is the answer to this riddle?



You might think that sound is something that must be heard. But you will discover that sound does not have to be heard. In fact, there are many sounds that man cannot hear.

In this unit we shall explore the form of energy called sound.

Place a ruler on the top edge of a desk so that about half of it sticks out beyond the desk. Hold down the other half of the ruler firmly on the top of the desk. Flip the free end of the ruler with your finger.

What happens? Do you see the free part of the ruler move up and down? Do you hear anything?

Now try this. Hold one end of a rubber band between your teeth. Hold the other end with one hand. Stretch the rubber band just a little. Now snap it with your free hand.

What do you see, feel, and hear? Do you see the rubber band move back and forth quickly? Do your teeth feel this movement? Do you hear anything?

Does anyone in the school have a drum you can borrow? If so, try this.

What do you feel? What do you hear when you hit the drum top with your fingertips? What reason can you give for the movement of the cereal flakes?

Strike the top of the drum. Put your fingertips lightly on the drum top. Do you feel the drum top move? Do you hear anything?

Sprinkle some dry cereal or any other light but dry material, such as dry sand, on the drum top. Now strike the drum top. Notice how the sand or cereal bounces on it. It moves about because the drum top is moving up and down. What do you hear?

When things move up and down or back and forth, as did the drum top, they are said to **vibrate** (VY-brayt). These movements are called **vibrations.**

What do you hear as you snap the rubber band?

The ruler vibrated when you flipped it, the rubber band vibrated when you snapped it, and the drum top vibrated when you struck it.

Each time something vibrated, you heard a sound. If you stop the vibration, the sound stops. *Without vibration there can be no sound.*

Is work being done when things vibrate? What is this work? You can feel many objects vibrate, and you can hear the sounds they produce. Sometimes, when big trucks rumble by, you can feel the ground vibrate under your feet.

Sometimes, when you are sitting in a car, you can feel the vibrations of the engine.

When a washing machine or a refrigerator is working, you can hear it. Can you feel it vibrate?

Have you ever put your fingers on the front of your radio when it was playing? What did you feel?

The vibrations of an explosion are very strong. After a big explosion, windows some distance away may be broken by the tremendous vibrations. Can you imagine the vibrations during an earthquake?

Sometimes you can both see and feel the vibrations of an object that is making sound. Sometimes it is not possible. But you can be sure that if you hear a sound, something is vibrating.

Can You Hear All Vibrating Objects?

Now you know that when something is vibrating, it may make a sound. But, can you *always* hear a sound when something vibrates? Now try this activity. Move your finger back and forth as

An earthquake caused much damage to this Alaskan town. Great vibrations were caused by the quake.

quickly as you can. Do you hear a sound? Your finger is vibrating but you hear nothing.

In order for you to hear a sound, something must vibrate between at least 16 times a second and about 20,000 times a second. You cannot wiggle your finger as fast as 16 times or more a second.

You heard a sound when you snapped the rubber band because it vibrated more than 16 times and fewer than 20,000 times in one second.

The number of times an object vibrates in a second is called its **frequency** (FREE-kwen-see). A frequency of twenty-five means that the object is vibrating 25 times a second.

The kind of sound you hear depends on the number of vibrations an object makes. Each sound has its own frequency. If you think back, you will remember that the ruler vibrated at a different frequency than the drum top. You could feel that they were different. And you heard different sounds.

Sometimes an object vibrates so fast that you cannot hear it. If it has a frequency of over 20,000 vibrations per second, you will not hear any sounds. Such very fast vibrations are called **ultrasonic** (ul-truh-SON-ik) vibrations.

A dog can hear ultrasonic vibrations even though you cannot hear them. A dog hears frequencies up to 40,000 vibrations per second. When you blow a special kind of dog whistle, you cannot hear a thing, but your dog will come running. This whistle has a frequency of more than 20,000 vibrations per second, so you cannot hear it.

PATHFINDERS IN SCIENCE

Robert Boyle

(1627–1691) England

Robert Boyle believed that a scientist not only should form hypotheses and do experiments, but should improve those that have already been tested.

Throughout his life, Robert Boyle was curious about the world around him. He found the world full of questions, puzzles, and problems. He believed that there was a pattern in nature. Scientists, he thought, could discover this pattern by experimenting.

One of the many problems that puzzled Boyle was how sound traveled. He

How Sound Travels

Let us suppose that you are in your home and your friend calls to you from the street. You hear the sound, even though there is some distance between you and your friend. How does the sound of his voice reach your ears? The *vibrating objects* are the vocal cords in his throat. As they vibrate, they push back and forth against the air in his throat. This push makes *waves* that travel through the air. You hear the sound when the waves reach your ear.

Vibrating objects have energy. Anything that has energy can do work. What kind of work can your vocal cords do? What matter do they push as they vibrate? The waves that travel through the air are the waves that cause you to hear sound. They are called **sound waves.**

You cannot see sound waves in the air, but you can learn about them.

wondered if air were needed. If a sound were made where there was no air, as in a vacuum, could the sound be heard? Boyle tried to find the answer by doing an experiment.

He hung a loud-ticking watch from the bottom side of a rubber stopper. He placed the stopper with the watch into a glass bottle that was connected to an air pump. The ticking sound of the watch was easily heard. Next, he pumped the air out of the bottle. The ticking became fainter and fainter. Soon no ticking was heard. He knew that the watch was still making sounds because he could see that the watch's hands were still moving.

Now Boyle slowly let air back into the bottle. He began to hear the ticking again. As he let more air in, the ticking became louder and louder. Boyle had shown that sound cannot travel through a vacuum.

His experiment was tested by others to make certain his conclusion was correct. You, too, can test Boyle's experiment. Instead of a watch, use a bell and a bell jar. What happens to the ringing of the bell when the air is pumped out of the jar? From what you have learned, explain why sound travels through gases, liquids, and solids, but not through a vacuum.

Robert Boyle is remembered not only for his many discoveries but also for his brilliance as an experimenter and as a teacher of the experimental method.

EXPERIMENT

How Do Sound Waves Travel?

What You Will Need

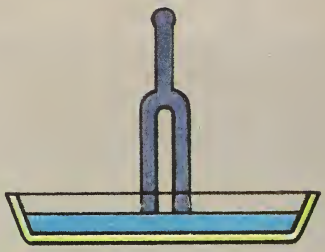
a rubber heel (or another piece of hard rubber)

tuning fork

small basin filled with water

How You Can Find Out

1. Strike the tuning fork against the rubber.
2. Hold the fork up to your ear.
3. Touch the top of the water in the basin with the vibrating ends of the fork.



Questions to Think About

1. What did you hear when you held the fork up to your ear?
2. What did you see when you touched the tuning fork to the water?
3. What work is being done here?
4. Where does the energy come from? Remember: Things in motion have energy of motion.

The vibrating fork makes the water vibrate and produces waves that travel out from the fork to the edge of the basin. These waves are like the waves that travel through the air.

When you touched the water with the tuning fork, waves traveled out on all sides from the vibrating fork. Now let's see how sound waves travel in air.

You will need a metal triangle like those used in an orchestra.

One pupil should sit directly underneath the triangle. Another pupil should stand on a chair so that his head is directly above the triangle. Other pupils should stand in a circle around it. Then strike the triangle.

Who heard it? What does this tell you about the direction in which sound waves travel from a vibrating object?

Are there any other things you could use in place of the triangle? Try some other things. See whether you get the same answer.

Do sound waves travel through other things besides air? Do sound waves travel through other things more easily than through air? The next experiment will help you find out.

Will everyone hear the sound? Use the picture to explain your answer.

EXPERIMENT

Do Sound Waves Travel Through Things Other Than Air?

What You Will Need

ruler alarm clock

How You Can Find Out

1. Make the ruler vibrate, as described on page 172.
2. Listen carefully to the sound you hear.
3. Do the same thing again. But this time, press your ear to the desk on which you are holding the ruler. Be sure you vibrate the ruler in the same way each time.
4. Put an alarm clock (or a watch) on the desk. Listen to its tick and then to its alarm.
5. Put your head on the desk and listen again to the tick and to the alarm.
6. Compare the sound of the waves as they travel through air and then as they travel through wood.

Questions to Think About

1. Is the sound louder when sound waves travel through wood? Why?
2. Do you think that sound waves travel better through all solid things than through air? Why?

You can also find out if sound waves travel better through air or through glass. Tap a windowpane. Listen. Tap it again, but this time put your ear against the windowpane.

Make up some experiments to compare how well the sound waves travel from a vibrating object. Try things made of metal. Then try things made of wood.

You will discover that these sound waves travel better through solid things than they do through air. The important thing to remember is that sound waves always travel through *something*—a solid, a liquid, or a gas.

Loud and Soft Sounds

How is a loud sound made? It's easy to find out. All you need are some radish seeds or cereal flakes, and a drum.

Put the seeds or flakes on the top of the drum. Strike the skin of the drum top softly. Watch the seeds bounce. Listen to the sound. Now strike the drum hard. Again look and listen.

Did you see the seeds bounce? Which time did they bounce higher? Which time was the sound louder?

As the drum skin vibrated, it pushed the air above it and made waves in the air. These sound waves pushed through the air in the room. Can you tell why the seeds bounced up and down?

The harder the drum skin was struck, the more strongly the sound waves pushed through the air. The more strongly the sound waves pushed through the air, the louder the sounds.

Now let's compare the sound waves made by loud and soft sounds. You will need a deep pan of water, a small ball or marble, and a larger ball or marble.

Drop the small ball or marble into the pan of water. Watch the waves. Now drop the large ball or marble into the pan. How are the waves different?

Sometimes you cannot hear a sound because the object that is vibrating is causing only very small vibrations. These vibrations cause small, weak sound waves.

A marble is dropped into a pan of water. On the right, a larger marble is dropped into the water. What differences do you see in the waves that are produced?

Using What You Have Learned

1. You can make a ping-pong ball bounce by touching it with a vibrating tuning fork.

   Glue one end of a piece of string to a ping-pong ball. Put the other end of the string under a book that is on a table. Leave enough string so that the ball hangs down at least two feet from the top of the table. Strike the tuning fork and carefully touch it to the ping-pong ball. What happens? Can you tell why?

2. A bat is an animal that makes sounds we cannot hear. Someone in your class can make a report on how bats use ultrasonic sounds for getting food and for flying around objects in the dark. These books may be helpful:

   Bats by Charles Ripper
   Sounds You Cannot Hear by Eric Windle

3. This is an illustration of the larynx. It is also called the voice box. Your larynx is in your throat.

   Place your hand gently on your larynx. Say your name. Do you feel vibrations? In the larynx are two strong, flat bands called vocal cords. When you speak, these vocal cords vibrate. Can you tell what makes them vibrate?

Look at the bottom half of the picture. Which view do you think shows what happens when you talk? Why do you think so?

What Makes Sounds Different?

Sounds are different in other ways besides being loud or soft. Some sounds are high and squeaky; some are low and deep. The song of a bird is not like the roar of an airplane. The sound of a drum is not like that of a violin. Let's find out now what makes the sounds different.

One important way in which sounds are different is in their **pitch**. Pitch is the word used to describe how high or low a sound is.

Differences in Pitch

What causes differences in pitch? To find the answer to this question, you will need a comb, a small card, and a book covered in cloth.

Hold the edge of a comb with one hand, as shown in the picture. With the other hand, rub the edge of a card slowly over the teeth of the comb. Listen to the sound. Now rub the card over the comb very fast. Listen to the sounds. Which sound was higher? Rub your fingernail slowly over the cover of a cloth-covered book. Then do it quickly. How are these sounds different? Can you tell why?

When you slowly rubbed the edge of the card over the comb, the card vibrated slowly. The sound you heard was low. When you rubbed the card faster, you heard a high sound. The sound was higher because the card was vibrating faster. The same thing happens when you make a rubber band vibrate slower or faster.

The faster an object vibrates, the higher the sound you hear. The slower an object vibrates, the lower the sound.

We can say this in another way: *The higher the frequency, the higher the pitch; the lower the frequency, the lower the pitch.*

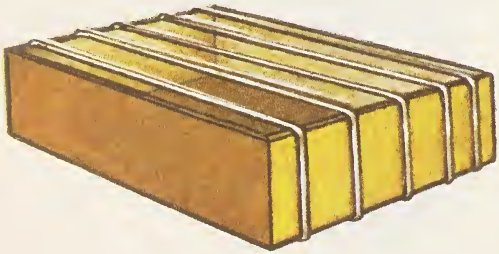
Thickness or Thinness Changes Pitch

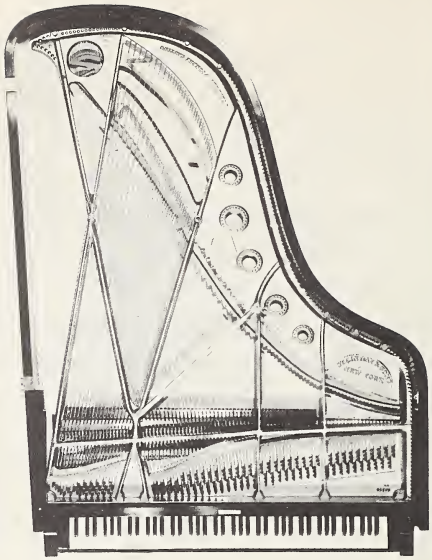
Even the thickness or the thinness of an object changes its pitch. To show this, you will need several rubber bands and an empty wooden chalk box without its lid.

Take several rubber bands of the same lengths, but of different thicknesses. Put them around the empty chalk box. Snap the rubber bands.

Which ones make the lower sounds? Which ones make the higher sounds? Can you tell which one vibrates fastest? Which one vibrates slowest?

Try using rubber bands of the same length and thickness. Then use rubber bands of different lengths but the same thickness. What happens?





Can you tell which side of the piano has the keys to strike for low notes by looking at the strings inside the piano?

A thicker object will vibrate more slowly than a thinner object of the same length and of the same material. A thicker vibrating object makes a lower sound than a thinner one.

If you can open a piano and look at the strings inside, you will see that the strings have different thicknesses.

Strike a low note. You will see a thick string vibrate. Strike a high note. What kind of string will vibrate?

You can see different kinds of strings on a guitar. Perhaps someone can bring a guitar to class.

What other instruments can you think of that use different thicknesses to produce different pitches?

You have found out that changing the thickness of a vibrating object is one way to change its pitch. This is because pitch depends on the number of vibrations per second. A thick object will vibrate fewer times in a second than a thin object of the same length. The faster the vibrations, the higher the pitch.

Length Changes Pitch

When you looked at the piano strings, you saw that they were of different thicknesses. You also saw that the strings were different lengths. Does the length of a vibrating object have anything to do with its pitch?

You can find out by changing the length of a vibrating object. You can show this with a rubber band.

Hold one end of the rubber band. Have someone hold the other end and then pull it tight. Snap the middle of the rubber band. Listen to the sound.

Next, hold the same rubber band near its middle. Pull the rubber band as tightly as before and then snap it. Listen to the sound.

Which sound was higher? Which vibrated with a higher frequency—the long rubber band or the short one? When two objects are of the same material and of the same thickness, the shorter one has the higher pitch.

Tightness or Looseness Changes Pitch

So far you have found out that the pitch of an object that vibrates can be changed by its thickness and its length. There is another way to change pitch.

A musician can change the pitch of a stringed instrument. The musician can tighten or loosen each string of his instrument so that each one has the correct pitch.

EXPERIMENT

What Does Tightening or Loosening a String Have to Do with Its Pitch?

What You Will Need

rubber band

How You Can Find Out

1. Have someone hold one end of a rubber band while you hold the other end.
2. Snap the rubber band. Listen to the sound.
3. Then, pull it tighter.
4. Snap it again and listen to the sound.

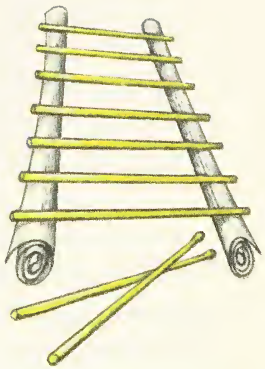
Questions to Think About

1. Which sound was higher?
2. When did the rubber band vibrate faster?
3. Find out how a harp works. How is the pitch changed on a string of the harp?

The tightness of a vibrating object helps determine its pitch. This tightness or looseness is called **tension** (TEN-shun). The tighter a string, the faster it vibrates and the higher the sound it makes. The looser a string, the slower it vibrates and the lower the sound it makes.

Let's review what you have learned about pitch. You have found out that pitch means how high or low a sound is when you hear it. Pitch has to do with the number of vibrations of an object. The faster the vibrations, the higher the pitch you hear. The slower the vibrations, the lower the pitch you hear. To change pitch, the frequency must be changed. This can be done by changing the thickness or the length of the vibrating object. With strings or wires that can be stretched, pitch can also be changed by changing the tension. This is done by tightening or loosening the strings or wires.

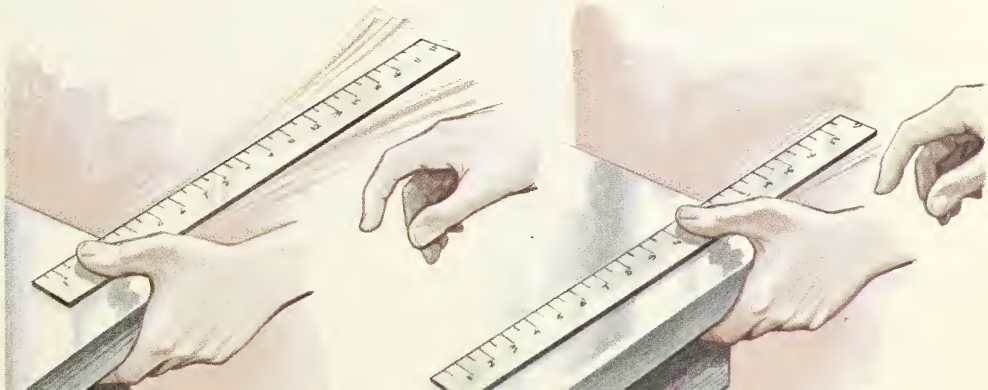
Using What You Have Learned



1. Now that you have learned about pitch, you can build your own musical instruments. One of the instruments you can make is a xylophone. Cut strips of different sizes from a piece of wood that is about an inch thick. You should cut strips that are from 6 inches to 18 inches long. Arrange them on two pieces of rolled-up newspaper as you see in the picture. When you play your xylophone, you will hear that the shorter pieces of wood make higher notes than the longer pieces.

2. Another instrument you can make is a rubber band harp. Put nails into a board as shown in the picture. Stretch rubber bands of different sizes over the nails. Some rubber bands should be thin and others thick; some should be long and others short.

3. Place one end of a ruler on a table. Put one hand on that end to hold the ruler firmly in place. Allow as much of the ruler to hang over the edge as possible. Flip the free end. Then make the part of the ruler hanging over the table much shorter. Flip the ruler again. When do you hear the higher sound? When do you hear the lower sound? Which time did the ruler vibrate more quickly?

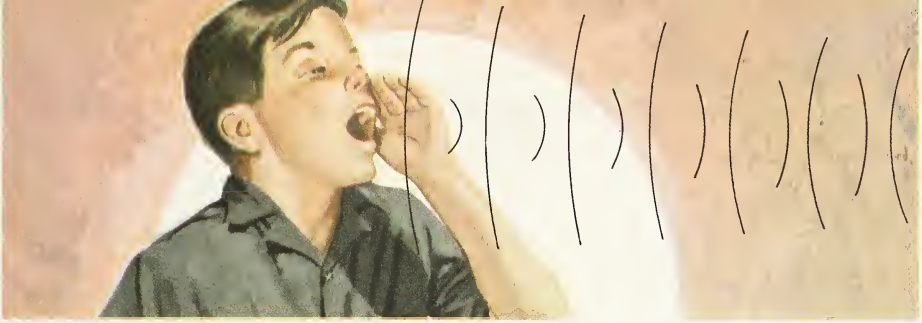


Reflected Sound Waves

Say a few words. Now put your face near the opening of an empty pail. Say the same words again in the same way.

Is there a difference? Did your voice sound louder the second time? The reason is that the sound waves bounced back from the inside of the pail. The sound waves were **reflected waves.** These reflected sound waves were added to those from your voice. Both kinds of sound waves reached your ear at the same time, so you heard a louder sound with the pail.

Do you like to sing in the bathtub or shower? One reason you may like to sing there is that your voice sounds stronger. The sound waves produced by your vocal cords bounce off the walls of the small room. You hear the waves produced by your vocal cords at the same time that you hear the waves that bounce off the wall. This makes your voice seem louder.



What happens to the sound waves produced by this boy shouting in a tunnel?

You hear both waves at the same time because sound waves travel through the air at a speed of about 1,100 feet a second. It does not matter whether the sound waves are weak or strong. They still travel through the air at this speed. When you sing in the bathtub or shower, the sound waves reach the walls and then bounce back. This happens so quickly that they seem to join perfectly with the sound waves that just came from your vocal cords.

Echoes of Sound Waves

In a large room or auditorium, sound waves have farther to travel before they are reflected. They do not join together quickly with the first sound waves, so the reflected sound is heard *later* than the original sound. When this happens, there is an **echo** (EK-oh). There can be an echo only when the object that reflects the sound is at least 55 feet from the source of the sound. If the distance is less than 55 feet, you will hear the original sound and the reflected sound at the same time.

A flat surface reflects sound better than a rough surface.

Controlling Reflected Sound Waves

Almost everyone has had the fun of shouting in a tunnel. Surely you have heard its great echoing noise. Can you explain what makes this noise?

In a tunnel, an echo can be fun to hear. But sometimes echoes are a nuisance. What can be done to control echoes in auditoriums and theaters, where echoes would make it difficult to hear clearly?

To answer this question, you need to test different kinds of surfaces to find out how they reflect sound.

EXPERIMENT

How Do Different Kinds of Surfaces Reflect Sound?

What You Will Need

empty drinking glass paper towel

How You Can Find Out

1. Hold the rim of an empty drinking glass against your ear.
2. Tap the bottom of the glass gently. Listen to the sound you hear.
3. Now stuff a paper towel into the drinking glass.
4. Tap the bottom again.
5. Listen to the sound you hear.

Questions to Think About

1. Which sound was louder?
2. Can you tell why it was louder?

When the sound waves were reflected from the smooth inside of the empty glass, you heard a loud humming sound. When the sound waves had to travel through layers of the rough paper towel, you heard a softer sound.

The smooth, hard glass surface reflected the sound waves very clearly. But the rough paper towel in the glass did not reflect these sound waves well.

In fact, the towel absorbed the sound waves. A paper towel is **porous** (POR-uss). It contains many air spaces that stop, or absorb, sound waves.

Materials are different in their ability to absorb sound waves. You can test different materials yourself.

First you have to choose the materials you want to test. Some things you might want to use are tissue paper, a pad of writing paper, aluminum foil, and cardboard.

When you have collected all the materials you want to test, get an empty pail. Line the pail with the first material you want to test. Hit the side of the pail and listen to the sound. Change the material and hit the pail again. Listen to the new sound. Test each one of your materials separately in the same way. Which material absorbed the most sound? Which material absorbed the least sound? Which one is the most porous? Which one is the least porous?

You can experiment at home, too. If you have a tiled bathroom, remove all the towels and bath mats. Then

Before you test the materials shown, tell which ones you think absorb sound the best.

sing any song you like, and listen to the sounds as you sing. Now put the towels back in place and sing the same song in the same way. Listen to the sound. When did your song sound louder? Why?

Curtains and draperies in rooms and auditoriums are not hung there just for decoration. They are porous, so they absorb sound waves.

Can you explain why rugs on a floor help to keep a room quiet?

Draperies, rugs, and curtains are not always enough to stop or to control all noise. In addition, other porous materials are used to absorb sound waves.

This singer is recording in a special room. What kind of material lines the room? Why?

Cork is one of these porous materials. Because it has thousands of tiny air spaces, it absorbs many of the sound waves. Such materials are often called **soundproofing materials**. They are used to absorb and control noises and echoes.

Look in your school cafeteria, your auditorium, and your gymnasium to see what kinds of walls and ceilings they have. Are they soundproof?

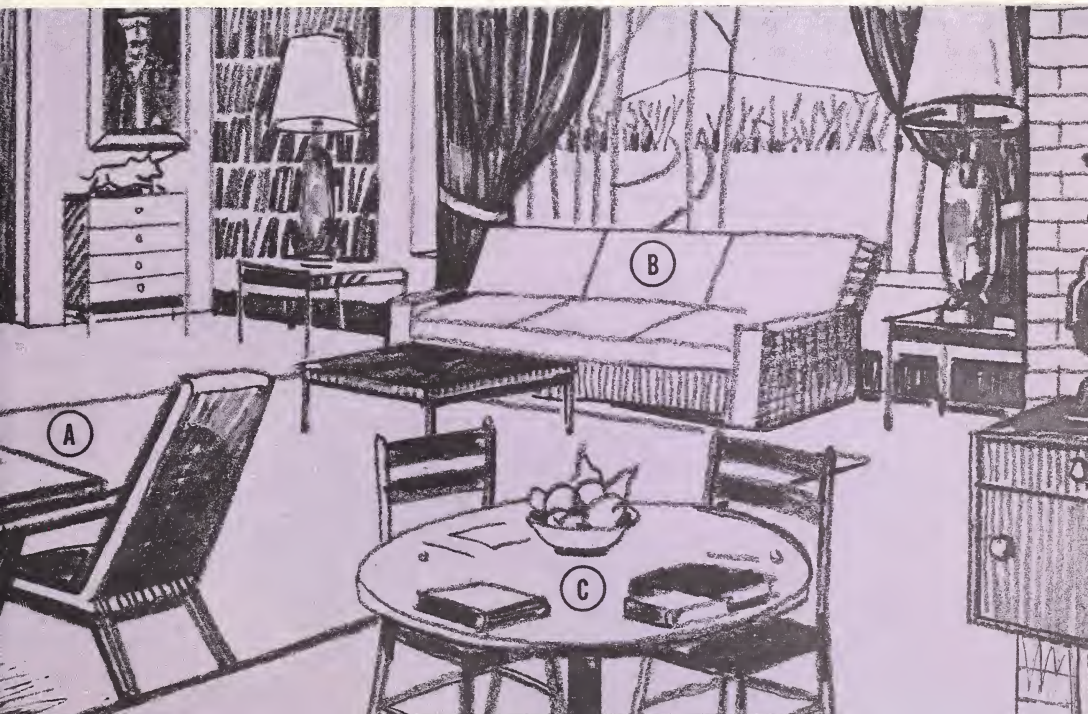
Planning for Noise Control

There are other ways of controlling noise. Schools are often placed away from the street so that street noises do not reach them. Often shrubs and trees are planted to act as sound wave absorbers. Playgrounds are often planned so that their noise does not reach the classrooms.

Look under your chair. Does it have wheels or rubber guards on the legs to prevent scraping noises? Look on the door to your classroom. Has the door a control on it to make it close quietly and slowly? What material is your classroom floor made of? If you are in a modern building, it may have floors of rubber or cork tile, which absorb sound waves.

Using What You Have Learned

1. Knowing the speed of sound helps man learn the depths of water and locate objects under water. Perhaps one of the pupils in your class would like to tell how scientists and engineers do this. He can look up *sonar* in an encyclopedia.
2. Do you think there are any sounds in outer space? What do scientists think about this question? How might you find out?
3. Can you hear things against the wind as well as with the wind? Why?
4. The picture shows a large room. A small group of people wish to have a discussion. Which spot—A, B, or C—would be best? Why?



WHAT YOU KNOW ABOUT

Sound—A Form of Energy

What You Have Learned

When you hear a sound, you are actually sensing **vibrations.** Vibrations are made when an object moves back and forth.

Some objects vibrate slowly, some rapidly. The number of times that an object vibrates in a second is called its **frequency.** You can hear a sound only if an object has a frequency that is between 16 vibrations each second and about 20,000 vibrations each second.

When an object vibrates more than 20,000 times each second, it makes an **ultrasonic sound.** You cannot hear ultrasonic sounds.

Pitch is the word used to describe how high or low a sound is when you hear it. Pitch depends on frequency. If a sound has a low frequency, you will hear a low pitch. If a sound has a high frequency, you will hear a high pitch.

Sometimes you can change the pitch of a sound and make it higher. You can do this by changing the thickness, the length, or the **tension** of the vibrating object.

A vibrating object makes the air around it vibrate in the same rhythm. The air vibrates each time the object vibrates. These movements of air are called **sound waves.**

Sound waves travel out in all directions from a vibrating object. When they strike another object, they may be **reflected,** or bounced back. These reflected sound waves are called an **echo.**

Sometimes we like to hear echoes. When we do not want to hear them, we use **soundproofing materials** that are **porous** (filled with holes). These materials absorb the sound waves and thus help to control unwanted noise.

Checklist of Science Words

Here are some science words you read about in this unit. Can you tell what you have learned about each one?

frequency	sound waves	ultrasonic
pitch	tension	vibrations

Find the Answer

Write the numbers 1 to 4 in your notebook. Next to each number, write the word that best answers the question.

1. What describes how high or low a sound is?
2. What do we call the number of times that an object vibrates each second?
3. What makes sound?
4. What do we call sound that we cannot hear?

True or False?

In each sentence below, a word is underlined. This word makes the sentence true or false. Write the numbers 1 to 4 in your notebook. If the sentence is correct, write "true" next to the number in your notebook. If you think the sentence is false, write in your notebook the word that will make the sentence true.

1. A thick object vibrates less in a second than a thin object of the same material.
2. The faster an object vibrates, the lower the pitch.
3. When two piano strings are of the same thickness, the shorter one has a lower pitch.
4. The tighter a string, the higher the pitch.

YOU CAN LEARN MORE ABOUT

Sound—A Form of Energy

Unscramble the Letters

1. Materials that absorb and control noises and echoes.
2. The number of times an object vibrates in a second.
3. The up-and-down, or back-and-forth, movements of an object.
4. Describes how low or how high a sound is.
5. Sounds which have such a high frequency that we cannot hear them.
6. The way sound travels through the air.

1. DOPOFOSGNUIRN
2. QUEENFRYC
3. SNAVBITORI
4. TCHIP
5. SLAUTRONIC DONUSS
6. NODSU VESAW

Make Your Own Telephone

You will need two tin cans, two buttons, and several feet of string.

Remove the top end from each can. Be sure that the edges are smooth. Now, punch a hole in the bottom of each can. Put the string through both holes and tie a button to each string end.

Have a friend talk into one of the cans while you hold the other one up to your ear. Pull on the cans just enough to make the string tight. Why can you hear your friend's voice?

Guess the Sound

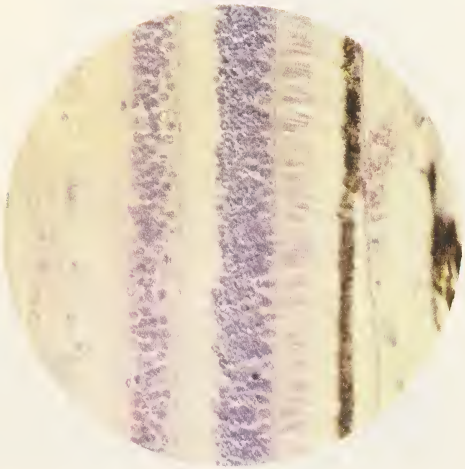
Have everyone in your class bring in one thing that makes a noise which someone in the class will recognize.

Divide the class into two teams. Blindfold two people (one from each team). Let your teacher make a sound with one of the things that someone has brought into class. The first person to guess what is making the sound gets a point for his team.

Then blindfold another pair and let them try to guess a different sound.

You Can Read

1. *Sound* by Marian E. Baer. Experiments you can do to learn more about sound.
2. *The Story of Sound* by James Geralton. A good book to read to learn more about sound.
3. *The Magic Sound* by Larry Kettlekamp. Another good book about how sound is made.
4. *The First Book of Sound* by David G. Knight. An easy-to-read book on the nature of sound.
5. *Sound and Ultrasonics* by Robert Irving. In this book you will learn how recordings are made.



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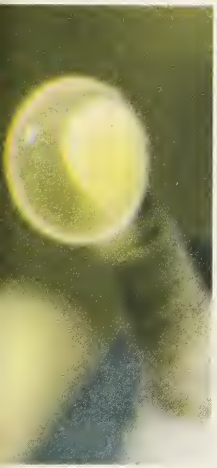


Light and Sight

Light Does Work

How You See

Did you know that you see only when the energy of light strikes certain cells in your eyes? Light energy makes it possible for you to see. How much of the world around you would you know about if light did not help you to see? Close your eyes for a few minutes. Then answer the question.

Light Does Work

You have already learned that light is a kind of energy. You also know that energy can do things. What are some things that light energy can do?

When you studied green plants, you found out that the energy of light changes materials to make food. This process is called *photosynthesis*. Such changes are called chemical changes. Sunlight can bring about chemical changes.

Have you noticed how some things change when they are put into the sunlight? You can see what happens by leaving a sheet of dark red paper in the sunlight for several days. Before you put the sheet into the sunlight, cover one half of it with black paper. This will keep sunlight from reaching half the paper. After several days, compare the covered half with the half that received sunlight. How did the sunlight change the paper?

Did you know that sunlight can make changes on the film in a camera? This happens every time you snap the shutter of your camera and then have the film developed into a photograph.

How Does Light Make It Possible to See?

Why can't you see objects in your room at night when the light is turned off? The objects are still there. You still have the same eyes. But when there isn't any light, you cannot see these objects.

How, then, does light make it possible to see?

If you turn on a lamp in a dark room, you will see the lamp. You see it because it is producing light. You

can also see other objects in the lighted room. The other objects are not producing light, but they are lit up. Then where does *their* light come from?

You have learned that light bounces off many objects that it hits. When this happens, we say that light is *reflected* from the object.

How Light Is Reflected

Most objects you see around you have rough surfaces. A rough surface reflects light in many different directions. Blotting paper, raw wood, and dirty glass are among the things that have rough surfaces. When light hits rough surfaces, it is reflected in many directions. Each little place on the rough surface reflects a little light in the direction of your eyes. To you the entire surface seems to be evenly lighted.

Suppose you polish the dirty glass, sand the wood until it is smooth and varnish it, and gloss the paper. You now have smooth surfaces. A smooth surface does not reflect light in many different directions. Look at the diagram to see how light is reflected from a smooth, shiny object.

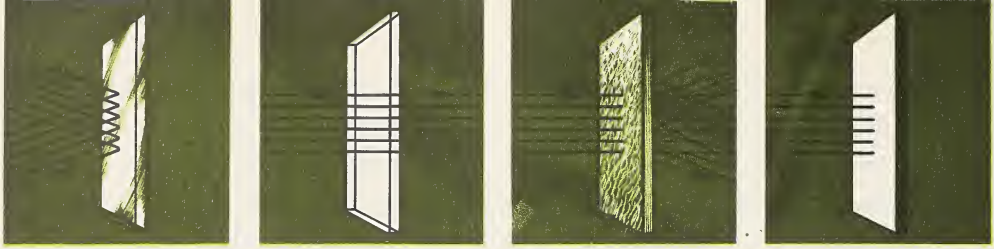
When light hits a smooth, shiny surface, most of the light is reflected to your eyes. Do you see how the light bounces off the smooth, shiny surface? Often light reflected from a shiny surface will hurt your eyes.

From what you know about reflection, answer these questions:

1. Should schoolbooks be printed on rough or glossy paper?
2. Should the walls of your room be painted with glossy paint?
3. How would you choose the best place for your reading light?

Materials that allow almost all of the light that hits them to pass through easily are **transparent.** How many transparent materials can you name?

Use the pictures below to describe what happens when light hits a rough surface and what happens when light hits a smooth surface. What are the differences?



Reflecting Transparent Translucent Opaque

Look at the pictures. What happens when light hits these materials?

Materials through which light cannot pass are called **opaque.** Wood and metal are opaque materials. How many other opaque materials can you name?

If light scatters in all directions on passing through a material, the material is **translucent.** Materials such as frosted glass, tissue paper, and waxed paper are translucent materials. Some light will pass through these materials, but not enough to allow objects to be seen clearly. How many translucent materials can you name?

Light-colored objects reflect most of the light that hits them. Dark-colored objects absorb most of the light that hits them.

Any of three things can happen when light hits an object:

1. It may be reflected.
2. It may pass through the material.
3. It may be absorbed.

All three things usually happen when light hits an object, but in different amounts.

You have learned that when light shines on an object, some of the light is reflected. When this reflected light reaches our eyes, we are able to *see* the object. For us to be able to see an object, it has to reflect some light to our eyes.

Look at different objects in your room. Each object reflects light to your eyes. Where does the light come from?

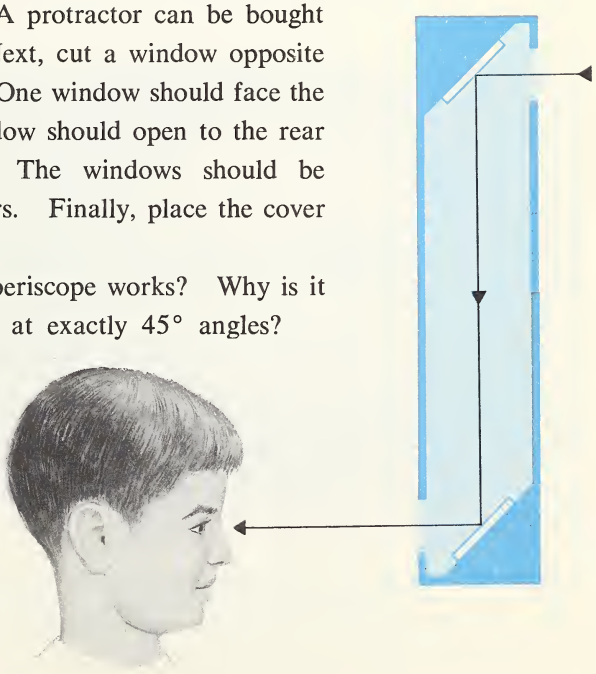
Hold this book at arm's length in front of your eyes. Can you see the objects that are behind the book? Are the objects still reflecting light? Why can't you see them? There are really two ideas that answer the question: (1) light will not go through certain things; (2) light travels in straight lines. How do these ideas answer the question? Keep these ideas in mind as you read about how you see.

Using What You Have Learned

1. Why is a book easier to read when it is printed on a paper with no gloss than when it is printed on shiny paper?
2. Find out how one-way mirrors work.
3. Demonstrate to your class how the reflecting mirror of an automobile headlight works.
4. Next time you enter a darkened room, note whether light-colored objects or dark ones are more easily seen after your eyes are adapted to the semidarkness.
5. From what you know, can you tell why a frosted light bulb produces less glare than a clear bulb?
6. One good way to learn how light is reflected is to build a periscope.

   All you need is a shoe box, two pocket mirrors, and tape. Fasten the mirrors at 45° angles across both ends of the shoe box, as in the picture. To measure and check your angle use a protractor. A protractor can be bought at a five-and-ten-cent store. Next, cut a window opposite the midpoint of each mirror. One window should face the upper mirror. The other window should open to the rear and face the lower mirror. The windows should be slightly smaller than the mirrors. Finally, place the cover on the box.

   Can you explain how the periscope works? Why is it necessary to place the mirrors at exactly 45° angles?



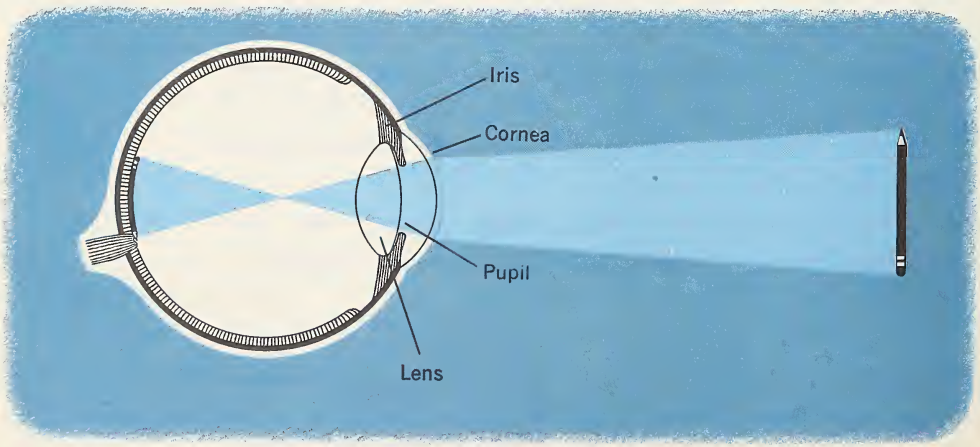
How You See

Let us trace the path that light takes as it enters your eyes. Light touches many parts of your eye. You cannot see all these parts. But some parts of your eye can be seen simply by looking into a mirror.

Light enters your eye through a clear covering called the **cornea** (KOR-nee-uh). Look at one of your eyes in a mirror. You cannot see the cornea, because it is like a thin sheet of colorless cellophane or glass. Do you see the circle of color? The circle of color is blue, brown, gray, green, or a mixture of two colors. Notice the black circle in the center of the color. This circle is really a space inside your eye. It is called the **pupil.** Light travels through the cornea and then goes through this space.

You may be wondering why the hole looks black. It looks black because the part of the eye behind the pupil is dark. If you make a small hole in a covered box, it will look black, too. This is because the inside of the box is dark. Try it and see.

Look at the circle of color again. The color has nothing to do with how well you see. This ring of color is



See page 202, Book 6, for a model that makes very clear to children why an upside-down image forms on the retina. Reproduce the model on the chalkboard and have children trace the path of each marble.

called the **iris** (EYE-riss). The iris is really a muscle. The iris can make the pupil bigger or smaller. The wider the pupil is opened, the more light can enter the eye. The most light enters your eye when the pupil is opened wide. When would your pupils be opened wide? When would they have the smallest openings?

You can watch your iris as it opens and closes the pupil of your eye. In a dark room, hold a mirror to your face. Now turn on a flashlight or a lamp near you. Watch in the mirror and see how the iris gets larger, making the size of the pupil smaller. This shows you what happens when you go out into the bright sun.

You have probably noticed that when you go from the bright outdoor light into a dimly lit theater, it is very difficult to see. After you are in the theater for a while, you can see much better. Can you explain how this happens? What does the iris of your eye have to do with it?

The light passes through the pupil and strikes the **lens**, which is behind

One picture shows what happens when you enter a brightly lit room. The other shows what happens in a dimly lit room. Which is which?

Use the pictures to identify the parts of the eye—the iris, the pupil, and the cornea.

Look at your finger and at the lamp. What do you see in focus? What does this tell you about the lens in each of your eyes?

the pupil. The lens in the eye is a little like the lenses in eyeglasses, in magnifying glasses, and in telescopes.

But there is one very important way in which the lens in the eye is different from these other lenses. The lens in the eye can change its own shape. There are muscles in your eyes that change the shape of the lens in each eye. The lenses in both eyes change at the same time. This makes it possible for you to see objects clearly when they are near or when they are far away.

When the lenses are changing their shapes so that you may see an object more clearly, we say that they are **focusing** (FOH-kuss-ing) on the object. When the object appears clearly for you, we say that it is *in focus.*

Hold your finger about six inches in front of your eyes. Now try to look at an object across the room and also at your finger, at the same time. One or the other will be blurred, or out of focus. The lens can change its shape very fast, but it cannot focus on both near and faraway things exactly at the same time. The lens can be only one shape at a time.

How the Lens Works

Lenses that are used for such things as eyeglasses and magnifying glasses are usually curved pieces of glass. As you have learned, light usually travels in a straight line. Light that goes through the lens, as you see on page 216, is bent as it passes into the lens from air. It is bent again when it leaves the lens.

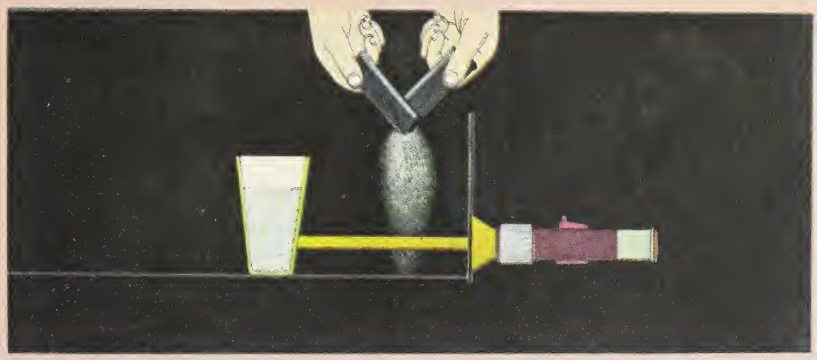
How Does a Lens Bend Light?

What You Will Need

glass, half-filled with water
2 chalkboard erasers
few drops of milk
piece of black paper
flashlight

How You Can Find Out

1. Put a few drops of milk in a glass half-filled with water.
2. Cut a small hole in a piece of black paper.
3. Now line up the glass of water and the black paper as shown in the picture.
4. Darken the room and make some dust in the air by clapping the chalkboard erasers together near the glass of water.
5. Shine the light from a flashlight through the hole in the paper, as is shown in the picture.



Questions to Think About

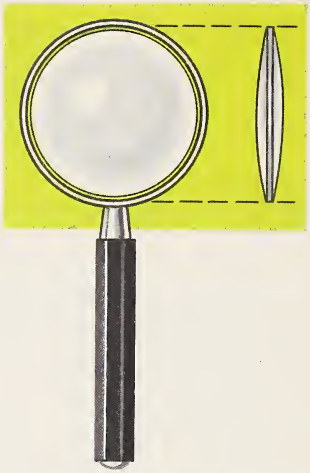
1. What do you see when you shine a light behind the hole in the paper?
2. How is the path of light different when you raise the paper?

How Light Is Bent

Light travels through the air at a speed of 186,000 miles per second. When light passes through something clear, like glass or water, it is slowed down a little. When a beam of light strikes glass or water at a slant, the part that strikes first slows down first. Since the rest of the beam is still traveling at the same speed, the beam is bent. You can see this happen. Put a pencil in a glass of water.

The pencil looks as though it were broken. The light reflected from the pencil leaves the water at a slant. This happens because a part of the light reaches the air sooner than the rest of the light. It reaches your eye sooner. This makes the pencil look as if it were broken. The light is bent.

Tell why the pencil looks broken.

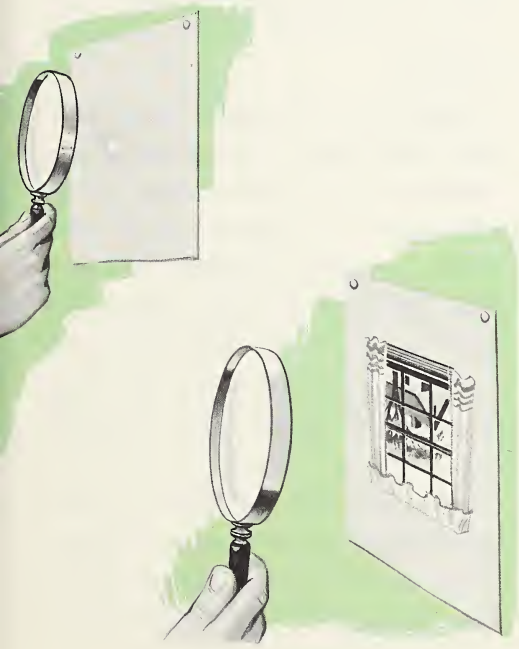


Is the glass in a magnifying lens flat?

Now you are ready to learn what the lens in your eye does. You will need a magnifying glass and a large piece of white paper. The glass in the magnifying glass looks flat, but it is not. It is thick in the middle and thin at the edges. Its surface is curved. It is a lens, and it will bend light passing through it. Since the magnifying glass is somewhat like the lens in your eye, we will use it to show what the lens in your eye does to light.

Stand across the room from a brightly lit window. Fasten the piece of white paper to the wall opposite the windows in your classroom. Hold the magnifying glass about three inches from the paper. Do you see a bright spot on the paper? Move the magnifying glass toward the paper until the bright spot becomes a picture that shows you clearly the shape of the window, upside down.

When the picture is clear, it is in focus. What did you do to the hand lens to get the picture in focus?

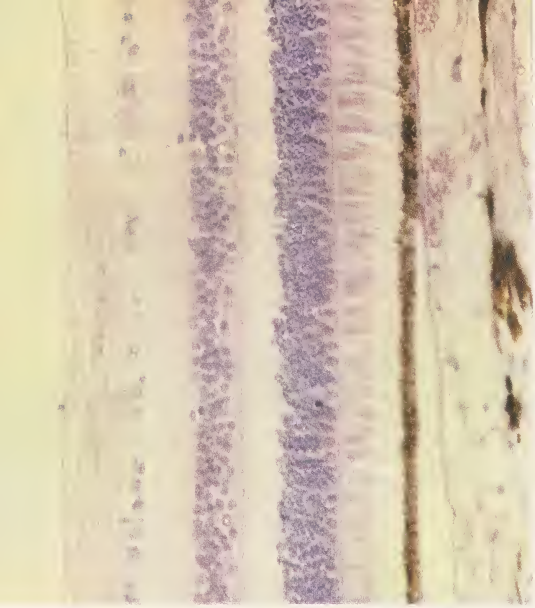


The lens in your eye bends light in almost the same way a magnifying glass bends it. But the lens in your eye does not move forward and backward in order to focus. Instead, the lens focuses when the eye muscles change its shape. The muscles make it more curved to see near objects. And the muscles make it less curved to see far objects.

The lens focuses a picture on the back of your eye. This picture is upside down. If the picture is upside down, how can we see things right side up? The answer is that your brain has learned to turn things so that they appear right side up.

The light passes through the lens of your eye. Next it goes through a colorless liquid that is like watery jelly. This liquid fills the center of the eyeball. Show where it is on page 204. The eye is sometimes called the "eyeball" because it is shaped like a ball.

Finally, the light strikes the very back of the inside of your eyeball. This part of your eye, which the light strikes last, is called the **retina** (RET-ih-nuh). The retina is like the piece of paper you used when you held up the hand lens to focus light coming in through the window.



Which are the cones? Which are the rods? How will you be able to find out?

How the Retina Works

As you will remember, your body is made up of many different kinds of cells. Within the retina are millions of cells. These cells are called **rods** and **cones,** because of their shapes.

The rods and cones receive the light after it travels through the eye. And so the rods and cones are called **light receiver cells.**

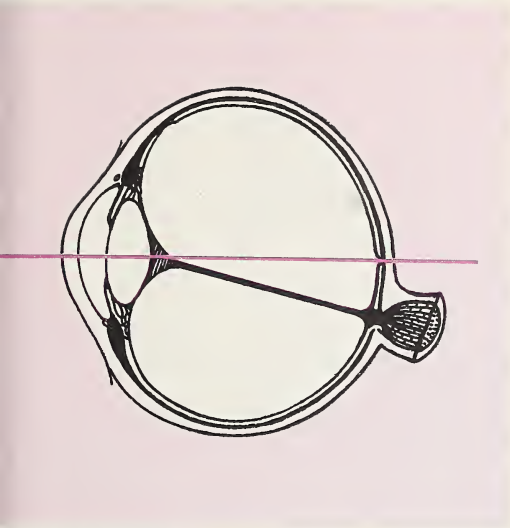
The rods and cones are very, very tiny. In each one of your eyes there are about 120 million rods and about 6 million cones.

You need both rods and cones for seeing. Each has a very special job to do.

The cones make it possible for you to see the difference in the color of things. Without the cones you could not see the difference between the colors of a bright red rose and a green leaf. Cones also allow us to see small shapes and fine lines. Without cones you could not read small print. The cones need a bright light. In dim light they do not work. That is why you cannot make out the colors of things in dim light. It is also why you find it hard to read small print when there isn't a good light.

The rods, on the other hand, work best in dim light. They are the light receivers you use when there is not much light. As nighttime comes, you use the rods more. When it is quite dark, you may see large shapes, but you cannot read the small letters in this book. That is because the cones do not have enough light to do their work.

The rods and the cones are not spread evenly over the retina. In some places there are more cones, and in some places there are more rods.



The fovea is an area on the retina, near the center, directly behind the pupil.

There is one place where there are only cones. It is called the **fovea** (FOH-vee-uh). This is near the center of the retina, in line with the pupil of your eye. Here the cones are packed very tightly together. This is the part of the retina that helps you see small things. It is the part of the retina you use when you read. The fovea is about the size of the period at the end of this sentence. As you read this line, the eyeball moves so that the light bouncing off the letters keeps falling on the fovea of each eye.

You remember that the rods do not help you to see color. They are the light receivers you use when there is not much light. Do you know why you cannot see color well from the corners of your eyes?

Here is something to try. Have a friend pick some brightly colored cards without telling you the colors. Pick one spot straight ahead of you and stare at it. Have your friend hold up a card and tell him to walk slowly around you from behind.

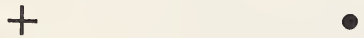
First you will notice that something is moving. You will not know what color it is. Then you will say, "It looks sort of . . ," and all of a sudden you will see that it is bright blue, or yellow, or whatever the color is. The rods will tell you that something is moving. But the color will not be clear until the cones near the center of the eye begin to receive the light from the card. When you see the color clearly, the light is focusing on the fovea.

When light falls on the rods and cones, they are changed in certain ways. These changes are signaled to the brain. The signals are sent through a nerve somewhat as telegraph messages are sent through a wire.

We actually "see" with our brains. The eye is our equipment for receiving light. It also changes the light into nerve messages that are carried to the brain. If something goes wrong with our light-receiving equipment, we may not be able to see. If something happens to that part of the brain with which we see, then even good eyes will not make it possible for us to see.

Where the nerve that goes to the brain is joined to the eye, there is a spot where there are no rods or cones. Light that falls on this tiny spot sends no messages to the brain. It is called the **blind spot.** You have probably never noticed the blind spot because you have two eyes. When the light falls on the blind spot in one eye, it falls on the rods or cones in the other eye, so you can still see.

You can see for yourself that you have a blind spot. Close your left eye. Hold the cross in the picture below about twelve inches from your face. Look at the cross with your right eye and move the book slowly toward your face. When the book is about ten inches away, the circle on the right will suddenly disappear. The light that is reflected from the circle will be falling on the blind spot.



Some People Need Eyeglasses

Scientists have found out a great deal about how light helps us to see and about how our eyes receive light. Using this knowledge, they can help people who have difficulty seeing.

In order for you to see well, the light that enters the eye must be focused on the retina. In some people, the eyeball is a little too long or a little too short. Then the lens does not focus light correctly onto the retina.

The pictures on the next page show the same view as seen by a person with normal vision, a nearsighted person, a farsighted person, and a person with astigmatism. A nearsighted person sees things that are near better than things far away. A farsighted person sees faraway things better. A person with astigmatism sees *parts* of objects out of focus.

Normal vision

Nearsightedness

WHAT PEOPLE SEE

At the top left is a scene as viewed by a person with normal vision. The other scenes show how people with eye defects see the same scene. What differences do you see?

Farsightedness

Astigmatism

Sometimes people are nearsighted or farsighted because the lenses in their eyes no longer change their shape as well as they should. When this happens, the lenses do not focus the light correctly on the retina.

These people are helped by eyeglasses. The lenses of eyeglasses bend

PATHFINDERS IN SCIENCE

Irving Cooper *(1922-)*
Charles Kelman *(1930-)*
Harvey Lincoff *(1920-)*

United States

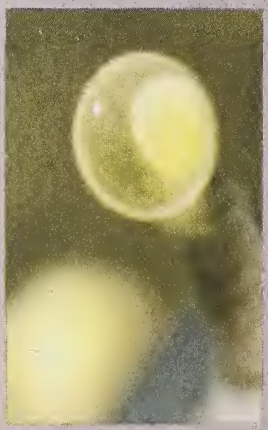
The retina of the eye is one of the most important parts of the eye. Here, the rod and cone cells are found. Sometimes the retina separates from the eyeball. When this happens, the retina's cells can no longer react to light, and sight is lost. Persons in whom this happens are said to have *detached* retinas.

About thirty-five years ago, **ophthalmic** (ahf-THAL-mik) surgeons (doctors who operate on the eye) discovered that by damaging the retina, they could cause scar tissue to grow. This scar tissue would form a new bond that would hold the detached retina in place. They thought that this method would help save eyesight.

Heat and chemicals were used to wound the retina. This was not an easy operation, and frequently other parts of the eye were damaged. Medical scientists and doctors needed a safer way.

The doctors may have found this way in **cryosurgery** (kry-oh-SER-jer-ee). Cryosurgery means cold surgery. A small, hollow knife, called a probe, is cooled to temperatures many degrees below zero. The probe is cooled with liquid nitrogen. The nitrogen is stored in the handle of the probe and flows to the probe's tip as the surgeon needs it. The surgeon can dial the temperature he needs.

A cold probe is used to freeze lens tissue. Below you see the frozen lens, a ball of ice.



the light before it passes through the lenses of the eyes. In this way, nearsighted and farsighted people can see as well as people who have good eyesight.

Look at the pictures on the next page. Observe how eyeglasses can correct nearsightedness and farsightedness, and how the lenses bend light.

After many experiments on rabbits, in 1962, Dr. Harvey Lincoff, Dr. John McLean, and Dr. Hugo Nano, of New York Hospital, tried cryosurgery on people with detached retinas. The results showed much less damage to the rest of the eye when the cold probe was used.

Today, surgery has this new tool for helping people with detached retinas. Cold surgery experiments are being done to find out if this method can be used for other eye defects and diseases.

No one man is responsible for this scientific discovery. Cryosurgery began when Dr. Irving S. Cooper, of St. Barnabas Hospital in New York, found he could safely put a tiny piece of the brain out of action by freezing it. Cryosurgery worked very well in patients with Parkinson's disease.

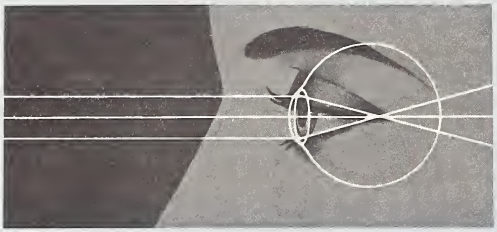
Eye surgeons began to wonder whether certain eye operations could be made safer by using cryosurgery. A young eye surgeon, Dr. Charles D. Kelman, experimented to find out if the cold probe could be used to make cataract operations safer.

In cataract, the lens of the eye becomes clouded, and vision becomes poor. The cure is to remove the lens. Glasses are then used in place of the lens. In the operation, the surgeon must pull the lens away from the parts of the eye that hold it in place. Sometimes one of the other parts is damaged in the operation.

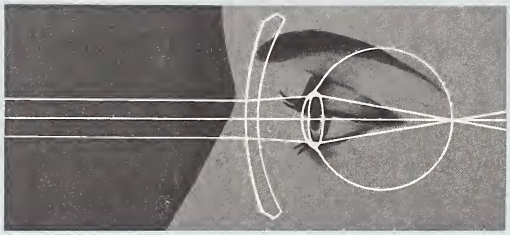
Dr. Kelman found that the cold probe caused the lens tissue to freeze into a ball of ice. When he pulled at the ball of ice, the pull was spread across a large area of the lens only—and did not harm any of the other eye tissues. This made a big difference. Dr. Kelman says that pulling a lens with forceps can lead to damage, but pulling a ball of ice is easier and helps to make a clean break.

After the successes of Dr. Cooper and Dr. Kelman, Dr. Lincoff and his associates also decided to experiment with cryosurgery. It was only after many experiments with animals that cryosurgery was used on human patients.

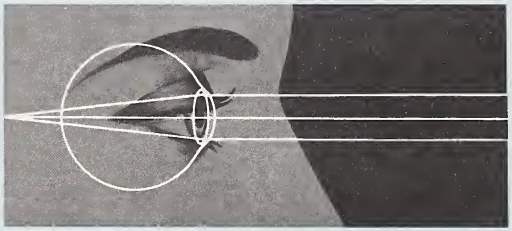
The use of a cold probe in eye surgery is just another example of how scientists build upon one another's work. Today's scientists build on the work of all those who went before them.

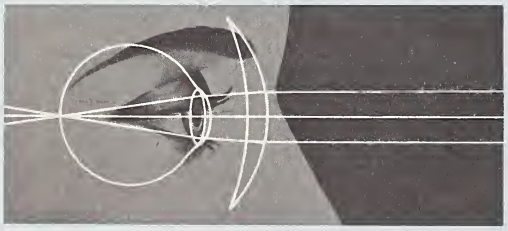


In a nearsighted person's eyes, the rays of light focus before reaching the retina. That is why the person sees near things better than he sees things far away. Below you see how eyeglasses correct this condition by making the rays of light focus on the retina.



CORRECTING POOR VISION





Above you see that a farsighted person's eyes focus the rays of light beyond the retina. That is why the person sees things that are far away better than he sees things that are near. Eyeglasses correct this condition by making the rays of light focus on the retina.

Using What You Have Learned

1. If you remember what happened to the pencil when you put it into water, you will be able to explain what happens in this experiment.

   Put a penny into a glass bowl of water. Make sure the penny is near the edge of the bowl. Starting from a place where you can see the penny, take steps backward until you get to a place where you can no longer see it. Now ask one of your classmates to pour water slowly into the bowl, making sure that the penny does not move. You will be able to see the penny again. Can you tell why?

2. You can find out about all the different kinds of jobs that have to do with the eye. Look up these words and then tell what each person does:

   optometrist (op-TOM-uh-trist)
   oculist (OK-yoo-list)
   optician (op-TISH-un)
   ophthalmologist (of-thal-MOL-uh-jist)

3. Form a committee and find out about seeing-eye dogs. Report to the class. Perhaps a blind person would be willing to bring his dog to your school and tell your class about him.

4. Explain how each of the following things is related to your eyesight and to automobile safety: (a) high and low beams, (b) blinking direction signals, (c) the distance a driver can see ahead at night, (d) special colors in taillights, (e) driving in fog, (f) the use of mirrors, (g) glasses for eye defects, and (h) colored glasses.

WHAT YOU KNOW ABOUT
Light and Sight

What You Have Learned

Light is a form of energy. Light makes it possible for you to see. You see objects only when light is reflected from them to your eyes.

Light enters the eye through the **cornea.** It goes through the **pupil.** Around the pupil is the **iris,** which controls the size of the pupil. The light goes through the pupil and strikes the **lens.** The lens **focuses** the light on the **retina.** Within the retina are millions of cells called **rods** and **cones.** They are called the **light receiver cells.** The cones help you to see small things, as well as the differference in colors. The rods work best when there is dim light.

For some people, light does not focus correctly on the retina because the eyeball is a little too long or a little too short. Eyeglasses may help these people to see as well as people who have good eyesight.

Objects may be **transparent, opaque,** or **translucent,** depending on the amount of light that can pass through them.

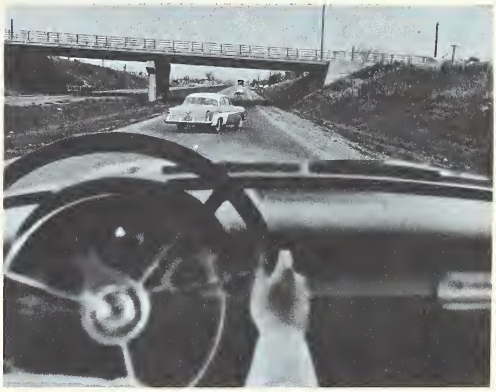
Checklist of Science Words

Here are some science words you read about in this unit. Can you tell what you have learned about each one?

blind spot	iris	retina
cones	lens	rods
cornea	opaque	translucent
fovea	pupil	transparent

Which Is Which?

Below are two pictures. One picture shows how a nearsighted person sees things. The other picture shows how a farsighted person sees things. Can you tell which is which?



Fill in the Answer

Write the numbers 1 to 5 in your notebook. Next to each number, write the answer that best completes the sentence.

1. The rods and cones are called the ___?___ ___?___ cells.
2. The place where there are no rods or cones is called the ___?___ ___?___.
3. The ___?___ cells make it possible to see the color of things.
4. The fovea is the one place in the retina where there are only ___?___.
5. The ___?___ cells work best in dim light.

YOU CAN LEARN MORE ABOUT

Light and Sight

Unscramble the Words

1. The ring of color that is a muscle.
2. Light goes through this hole.
3. Clear covering of the eye.
4. There are no rods or cones here.
5. They make it possible to see in dim light.
6. This focuses as you look at things.
7. This is like a screen on which the lens focuses the light.
8. There are no rods here.
9. They make it possible to see color.

1. SIIR
2. PILPU
3. ANORCE
4. DIBLN OTSP
5. SDOR
6. SELN
7. NETIRA
8. EVOFA
9. SOCEN

You Can Do This

Roll up a sheet of paper into a tube that is about one inch round. Hold the tube up to your left eye. Now hold your right hand next to the tube about eight inches away from your eye. Look through the tube with your left eye, and at the same time look at your hand with your right eye.

Do you see a hole in your hand? Do you know why?

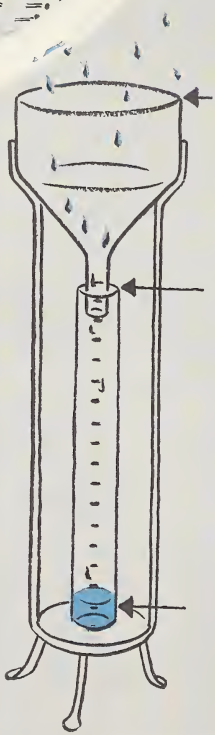
You Can Make a Model of the Eye

You will need a rubber ball, some cardboard or a piece of wood, and paint of different colors.

Cut the rubber ball in half and paste it onto the cardboard. With your paints, paint on the different parts of the eye. After you have painted on the iris and the pupil, take clear cellophane and put it over the eye. This will stand for the cornea. Now think of some materials for eyelashes and eyebrows.

You Can Read

1. *Experiments in Optical Illusion* by N. Beeler and F. Branley. Many experiments with optical illusions.
2. *Wonders of Your Senses* by Margaret Cosgrove. Vision is one of the senses you will read about.
3. *Our Wonderful Eyes* by John Perry. Tells how we see and how to care for our eyes.
4. *The Wonder of Light* by Hy Ruchlis. Tells how light acts.
5. *The Story of Eyes* by S. Sutton-Vane. A more difficult book for those who want to find out more.



This hole

is 10 times

as big as

this hole.

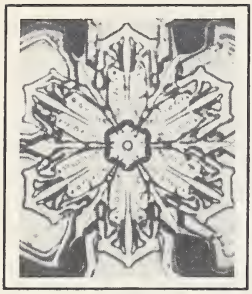
When 1/10 inch of rain falls into the funnel, it will make 1 inch of water in the tube.

8

Weather in Your Life

What Is the Weather Going to Be Like?

How Air Acts



The news reporter says, "Coming up in a minute, the weather forecast for today." And people in every part of the country stay tuned to their radio or television sets to learn what the weather is going to be like. After the forecast is over, many people will plan their day according to the weather forecast.

What Is the Weather Going to Be Like?

You have probably looked up at the sky the night before a picnic and said, "It looks cloudy. I think it is going to rain tomorrow." Or, perhaps while playing, you suddenly noticed that it was getting dark and the air was becoming very still. Then you said, "We'd better run for cover. It's going to rain any minute." Five minutes later the rain came. You had correctly **forecast** the weather. When you forecast the weather, you try to tell what the weather will be like sometime in the future.

You probably have correctly forecast the weather many times, but only for a day or so ahead. Could you forecast the weather for next week or next month? No, because there is more to weather forecasting than simply looking up at the sky and making a guess.

Weather forecasting is now done by weather scientists working in **weather stations.** If you were to visit a weather station, you would find the weather scientists using maps and charts and all kinds of special instruments—such as a **rain gauge** for finding the amount of rainfall. The scientists even use balloons of all sizes. Being a good weatherman is a difficult job. Let's find out more about the weather scientist and what he does.

Studying the Weather

The weather scientist has found that when there is a change in the **temperature** of the air, the pressure of the air, and the amount of water in the air, we will get different kinds of weather. Water that is in the air is called **water vapor.** Water vapor is made of very

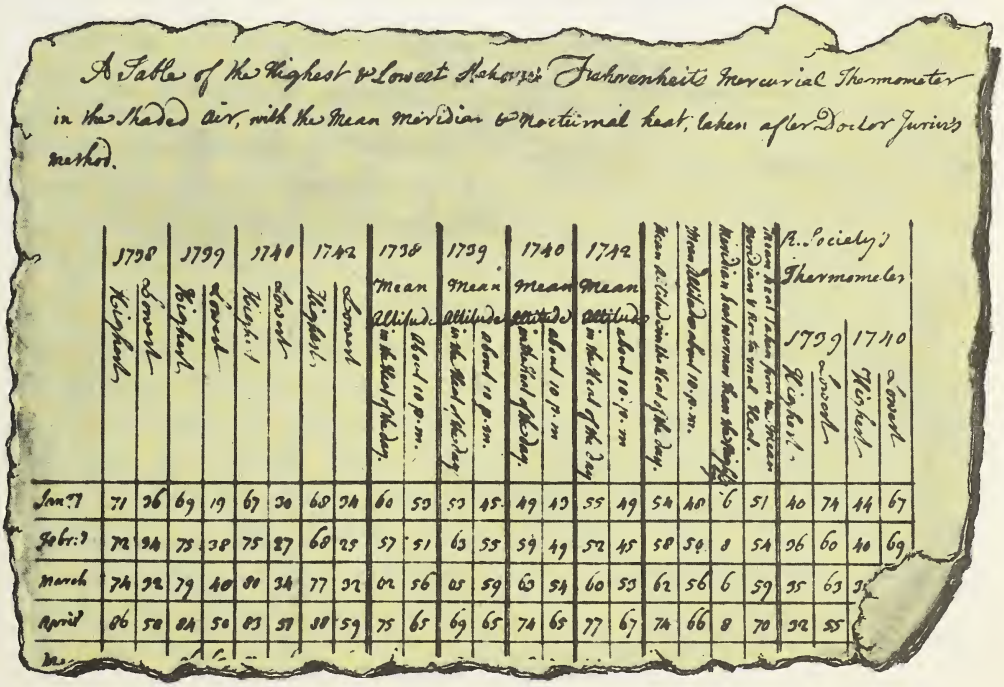
small particles. You cannot see water vapor in the air.

For many years, weather scientists have been keeping records of air temperature, **air pressure,** and water vapor at different times each day. They have also kept records of the kind of weather made by the different conditions. These records help weather scientists to compare weather conditions. The records help them to make better forecasts. However, weather scientists still have a great deal to learn about the weather.

Early History of Weather Forecasting

A little over 200 years ago, in 1753, Dr. John Lining, of Charleston, South Carolina, started using scientific instruments to observe the weather. Every day at 6:30 in the morning, 3:00 in the afternoon, and 10:00 at night, he measured rainfall and wrote down the air temperature, the air pressure, and the amount of water vapor in the air. He studied the direction and speed of the wind. His records were continued for

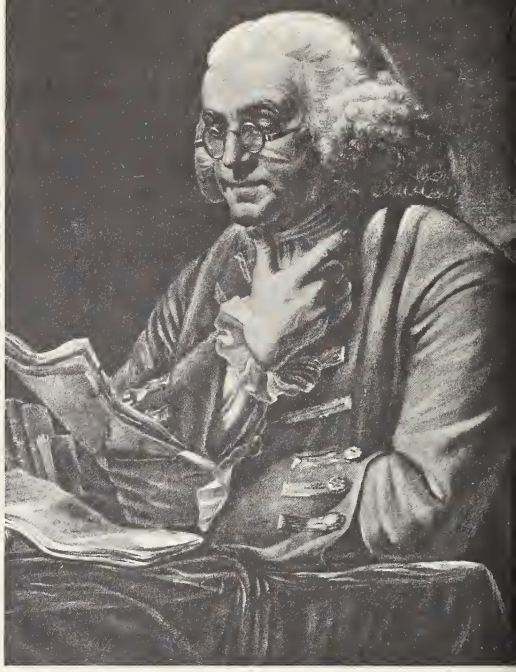
One of Dr. John Lining's original records is shown below. Can you read some of the weather observations he made over 200 years ago? Can you find out more about him?


A Table of the Highest & Lowest Heights of Fahrenheit's Mercurial Thermometer in the Shaded Air, with the Mean Meridian & Nocturnal heat, taken after Doctor Jurin's method.

	1738 Highest	1738 Lowest	1739 Highest	1739 Lowest	1740 Highest	1740 Lowest	1742 Highest	1742 Lowest	1738 Mean Altitude at 10 p.m.	1738 Mean Altitude at 10 p.m.	1739 Mean Altitude at 10 p.m.	1739 Mean Altitude at 10 p.m.	1740 Mean Altitude at 10 p.m.	1740 Mean Altitude at 10 p.m.	1742 Mean Altitude at 10 p.m.	1742 Mean Altitude at 10 p.m.	Mean Altitude at 10 p.m.	Mean Altitude at 10 p.m.	Mean Heat taken from the Mean Meridian between the highest & lowest Heat.	Mean Heat taken from the Mean Meridian between the highest & lowest Heat.	R. Society's Thermometer 1739 Highest	R. Society's Thermometer 1739 Lowest	R. Society's Thermometer 1740 Highest	R. Society's Thermometer 1740 Lowest
Jan.y 1	71	36	69	19	67	30	68	24	60	53	53	45	49	43	55	49	54	40	6	51	40	24	44	67
Febr.y	72	34	75	38	75	27	60	25	57	51	63	55	59	49	52	45	58	50	8	54	36	60	40	69
march	74	32	79	40	80	34	77	32	62	56	65	59	63	54	60	53	62	56	6	59	35	63	35	
April	86	50	84	50	83	37	80	59	75	65	69	65	74	65	77	67	74	66	8	70	32	55		
May																								

a hundred years by the Medical Society of South Carolina. As a result, Charleston, South Carolina, has the oldest records of temperature and rainfall in the United States.

It was Benjamin Franklin who first recorded that storms usually come from the south or southwest. He made this observation in 1748 by putting together the weather reports sent to him by mail from different parts of the country. During Franklin's time, the mail moved much more slowly than the weather. Until a faster way could be found to get weather reports from one part of the United States to another, no one could accurately forecast the weather.



Among many other achievements, Benjamin Franklin kept many records of weather conditions.

The Telegraph Reports the Weather

For about a hundred years, scientists worked hard to find a way to get weather reports quickly so that the movement of storms could be forecast. Then, in 1837, the telegraph was invented by Samuel F. B. Morse. A plan was made to have fifty-four telegraph companies in different parts of the United States send their local weather conditions to the Smithsonian Institution, in Washington, D.C.

Every morning the superintendent in the head telegraph office would telegraph the local operators, "Good morning, what is the weather?" The local telegraph operator tapped his key and reported the local temperature, wind, and other weather information. The head office then telegraphed these facts to the Smithsonian Institution, which in turn recorded all the reports from different parts of the country. These reports were put on a large

weather map posted on their wall in Washington, D.C. Weather scientists could gather reports and make forecasts within one hour after obtaining weather information from different parts of the country. Unfortunately, the Smithsonian Institution had no way of broadcasting this information.

Weather Bureaus Are Set Up

Then, eight years later, a French scientist, named Urbain Leverrier (ur-BAN leh-vehr-ee-AY), drew up a plan for an *international system* of telegraphic reports. In 1853, the French weather service was started. The United States followed with a weather service in 1870. It was now possible to forecast the weather with greater accuracy.

Today, weathermen make hourly weather reports in every part of the country. They study these reports and compare them with past records, as well as with present weather conditions. Then they make their forecasts of how the temperature of the air, the pressure of the air, and the amount of water vapor in the air will change. It is the changes in these three conditions that make our weather change.

Following the Weather

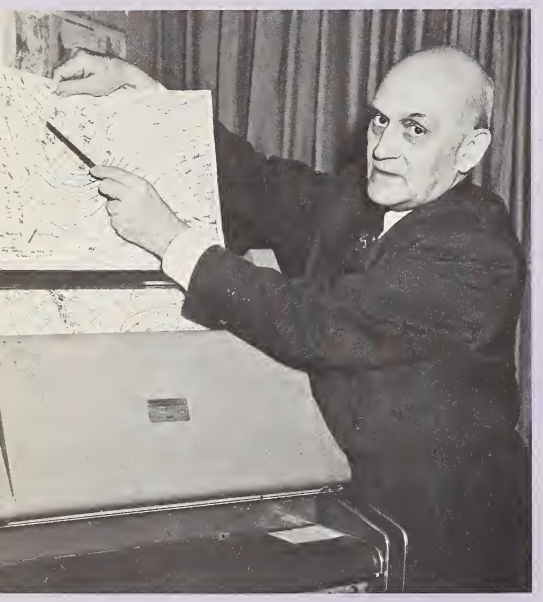
The weather in your town today is the result of certain conditions that may have started hundreds or even thousands of miles away. The weather that your town will have next week may be starting right now in some far-off place. And at this very moment, scientists at the weather station nearest your home are studying the travels of these weather conditions.

When the weatherman forecasts "fair during the day and rain at night,"

Leverrier drew up a plan for an international system of telegraphic reports of weather conditions.

don't blame him if you get caught in a shower at lunch time. With all the many ways in which weather conditions can suddenly change, he still does a fine job of forecasting the weather. Why don't you test the weatherman? Make a record of the weather forecasts for two weeks and compare it to the actual weather. *Then* ask, "How accurate is the weatherman?"

The work of forecasting the weather begins by understanding how the temperature, air pressure, and water vapor in the air change—and what causes them to change. To understand this, you must first study the air, where all these changes take place. Then you will better understand how changes in the air make the weather, and why the weather can change so suddenly.



PATHFINDERS IN SCIENCE

Francis W. Reichelderfer

(1895–) United States

In 1963, after twenty-four years as chief weatherman for the United States, Dr. Francis W. Reichelderfer retired. To him, weather forecasting has been a fascinating game of always trying to "beat the weather."

When Dr. Reichelderfer started his career, weathermen flew kites and balloons to gather information about the weather. Early in his career, Dr. Reichelderfer served as co-pilot in a two-man weather-forecasting balloon. There, he learned how to record the temperature, humidity, air pressure, and wind speed. He also

observed cloud formations, cloud types, and cloud movements.

Under Dr. Reichelderfer's leadership, the U. S. Weather Bureau began rocketing earth satellites into orbit to probe the atmosphere. Clear photographs of clouds have been radioed directly to the Weather Bureau from the various Tiros satellites which circle the earth. These photographs have identified the cloud patterns that are usually found with certain types of storms. The satellites have been able to probe areas of our universe never before explored by weather forecasting instruments.

It is hoped that in the near future, local weather forecasters will be able to use the weather information from these satellites as easily as they now use information from barometers and thermometers. By using many scientific instruments, today's weather scientists are able to forecast the weather correctly 85 to 90 per cent of the time. Their forecasts are helpful for everybody.

The Weather Bureau, under Dr. Reichelderfer's guidance, started many public services. Among them were crop forecasts for farmers, weather reports for airplanes and ships, and reports on floods and hurricanes. The Bureau now has services that were not thought possible when Dr. Reichelderfer became chief weatherman. Such services are weather forecasts for manned space flights, for rocket flights, and for nuclear tests.

Dr. Reichelderfer is truly a pathfinder in weather forecasting.

Air Takes Up Space

As you already know, there is air all around you. But you cannot see it, or taste it, or smell it. You can tell that it is there when you feel it moving. Air that is moving is called **wind**. When you are inside your home, how can you tell whether the wind is blowing outside? What are some things you can look for?

Air is a mixture of oxygen, nitrogen, and other gases. There are layers of air surrounding the whole earth. These layers form what is called the **atmosphere** (AT-muh-sfeer).

Air fills up space that looks as if it were empty. When you look at a bottle and cannot see anything in it, you may say the bottle is empty. But is it really empty? You can find out.

EXPERIMENT

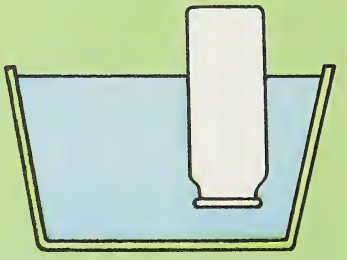
Is an "Empty" Bottle Really Empty?

What You Will Need

vegetable dye 2 bottles pail of water

How You Can Find Out

1. Put a small amount of vegetable dye into a pail of water. Color the water with dye so you can see the water better.
2. Push one "empty" bottle upside down into the pail of water. Hold the bottle with the mouth straight down.
3. Now tilt the bottle. What do you see?
4. Push another "empty" bottle down beside the first bottle.
5. Tilt the second "empty" bottle so that a bubble comes out. Catch the bubble in the first bottle. Continue to do this until there is no water in the first bottle.



Questions to Think About

1. Can you "pour" the air from one bottle to the other?
2. What is now in the first bottle? What is in the second bottle?

Air fills all openings, even if the openings are small. If you push more air into a container, the air pushes harder against the walls.

If the walls of the container can stretch, the added air will push them out. You can see this when you blow up a balloon or pump air into a tire.

Does Air Press on Things?

What You Will Need

glass pail of water

How You Can Find Out

1. Push a glass into a pail of water.
2. Let the glass fill with water. While it is still under water, turn the glass upside down.
3. Lift the glass of water straight up. Lift it high enough so that only the rim of the glass stays below the water.
4. Now lift the glass a bit higher so that the open end is above the level of the water in the pail.

Questions to Think About

1. What happens when you lift the glass so that the open end is just below the level of the water?
2. How does this show that air presses on things?

In this experiment, the air presses down on the water in the pail. The air presses down on the bottom of the glass, too, but the glass keeps the air from pressing down on the water inside the glass. All the air pushing down on the water in the pail is heavier than the water inside the glass. The weight of the air holds up the water in the glass.

You have now learned two important facts about air. Air takes up space, and air has weight.

The air is made of very small parts called **molecules** (MOL-uh-kyoolz). These molecules are much too small for you to see. All objects are made of molecules.

Air molecules are always moving. They are bouncing around in all directions. If air is heated, the molecules will move faster and bounce farther apart from each other. In warm air, the molecules are farther apart than in cold air. There are not as many air molecules in a gallon bottle of

50° F. 75° F.

On the left is a closed room. Is the air moving? On the right the heat is turned on. What happens to the molecules of air in this room?

warm air as there are in a gallon bottle of cold air. Therefore, a gallon of warm air weighs less than a gallon of cold air. In the gallon of warm air, the faster-moving air molecules spread farther apart, so that fewer of them fit into a bottle. In the bottle of cold air, the slower-moving molecules are closer together, so that more of them are crowded into the bottle.

How Air Moves

Can you feel the air? Not unless it is moving. When you use a fan to push the air, you can feel the air move. You have made a *wind*. Wind is air that is moving. We will need to find out more about air to understand what makes it move.

You have learned that warm air is lighter than cold air. Then, of course, cold air is heavier than warm air.

You might ask, "What does this have to do with the weather?" Let us suppose that it has become cold in your room. The temperature is 50° F. The molecules of air in the room are moving at a slow speed. Now, suppose you turn on the heat. As the air becomes warmer, its molecules move faster and push farther apart. In the warmer part of the room, where the heat is coming from, there are fewer air molecules than in the cooler parts.

Now let us see what is happening on the cooler side of the room. In the cold air the molecules are crowded more closely together than they are in the warm air. The cold air molecules move across the floor toward the area where the air is warmer and lighter. There is more room there. The cold air now becomes warmer and, therefore, lighter. As it becomes warmed, more cold air moves in and it pushes the warmer air up and across the ceiling to the other side of the room. But as it gets to the cooler side of the room, it again becomes cooler. It sinks to the floor and moves again toward the warmed side of the room.

The hotter the air becomes, the faster it moves up, across, down, and back. From what you have just learned, explain what happens to the air in a room when you open windows from top and bottom. What happens when the air on both sides of the room becomes heated to the same temperature?

Let us now find out how outdoor air gets heated. We would need a giant-size radiator to heat all the air. The *earth* is this giant radiator. When energy from the sun has warmed the earth, the earth becomes a huge radiator. You have felt how hot the sand at the beach can become. The sun heats not only the sand, but all kinds of soil and rocks and water. Just as the radiator in your room heats the air nearest it, the earth heats the air nearest it. This causes the molecules making up the warm air nearest the earth to move faster and farther apart. The warmed air also becomes lighter as this happens. It is pushed up by the cooler air, just as the air in your room is pushed up when it is warmed.

The Weather Is Different in Different Places

You know that the weather is not the same everywhere. Do you know why? Here are some of the reasons. The surface of the earth is different in many places. Some places are covered with rocks or soil or sand. There are forests, mountains, prairie lands, and deserts. Other parts of the earth are covered with water. There are streams, rivers, lakes, and oceans.

Does the sun heat all these different surfaces exactly the same amount? You can find out easily by doing the next experiment.

EXPERIMENT

Does the Sun Heat All Surfaces the Same Amount?

What You Will Need

soil	2 coffee cans
water	thermometer

How You Can Find Out

1. Fill one coffee can with soil. Measure its temperature.
2. Fill the other coffee can with water of about the same temperature as the soil.
3. Now put both cans on the same sunny window sill for 20 minutes.

Questions to Think About

1. Do the contents of the cans feel alike in temperature?
2. Now use a thermometer. What does the thermometer read for each can?

You have just found that, in sunlight, soil heats up faster than water. Most materials heat up faster than water. Buildings and sidewalks all heat up faster than water.

Land heats up faster than water. That is why people who live in the city go to the beach or a swimming pool in the summer to cool off. One of the reasons that land heats up faster is that sunlight heats the surface of the soil, but it cannot easily pass through the soil to heat the part below the surface. Most sunlight warms only the surface of the earth. But the same amount of sunlight can shine right *through* water and can heat the water down to a certain depth.

Have you ever looked down at the earth from an airplane or from a high lookout on a mountain road? If you have, you have seen that the earth is not the same color everywhere. Some places are dark-colored and others are light-colored. Some are green, others are brown. Could this make a difference in the way the earth is heated by the sun? You can find out.

Are Things of Different Colors Heated Equally Fast by the Sun?

What You Will Need

large pieces of white, red, blue, and black cloth
thermometer

How You Can Find Out

1. Put pieces, about 5 inches by 5 inches, of white, red, blue, and black cloth in a sunny window.
2. Feel them with your hand after a while. Are some of them warmer than the others?
3. If you have thermometers, place one under each of the pieces to make sure.

Questions to Think About

1. What is the temperature under each piece of cloth?
2. Why should you try to use a thermometer rather than your hand to see which is warmer?

Look at the patches of land. Are they heated differently? Explain your answer.

You have found out another reason that land heats up faster than water. *Darker things usually heat up faster than lighter ones, and most land is darker than water.*

Here is another reason for the differences in the way the earth is heated by the sun. On a hot sunny day, when you are outdoors, you feel much cooler when a cloud comes between the sun and the earth. Clouds shade the earth. When this happens, the sun cannot heat the shaded places as much. You can show how this happens.

This picture shows how clouds shade various parts of the earth. Can you tell how this shade affects the amount of heat different parts of the earth receive?

Does Being in the Shade Affect the Temperature?

What You Will Need

2 glasses of water large piece of paper thermometer

How You Can Find Out

1. Take the temperature of the water in each glass.
2. Now put them both near the same sunny window.
3. Place a large piece of paper over only one of the glasses. (This paper covering is your "cloud" and throws a shadow on the water.)
4. After an hour, take the temperature of the water in each glass again.

Questions to Think About

1. Compare the temperatures. Which one is warmer?
2. Can you think of another experiment to do that shows how being in the shade changes the amount of heat an object gets?

Take the two coffee cans—one with water, the other with soil—that you used for your experiment on page 234. Before leaving school for the day, use a thermometer to find the temperature of the soil and the water. Next morning, as soon as you get to school, take the temperature again. Is there a change?

At night, the soil and water on the earth are no longer heated by the sun. They lose heat and become cooler. From the experiment that you just did, using the water and the soil, you found that *soil cools off faster than water does.*

Making Winds

During the daytime the sun warms the earth. And so the air over the land becomes warmer than the air over the water. The cooler, heavier air moves in from the water and pushes

After reading the text below, study the pictures above very carefully. Then see if you can describe what is happening in each of the pictures.

the warmer, lighter air up. The air moves in a big circle. The air goes up from the land across to the water and down toward it. Then it moves across, toward the land, up, back across toward the water, and down again. This happens over and over again. The wind blows from the water to the land as long as the sun keeps the land warmer than the water.

At night, the land and the water are no longer heated by the sun. They lose heat. They get cooler. You already know from the experiment on page 234 that the land will cool much faster than the water.

At night, when the air over the water becomes warmer than the air over the land, the air again moves in a big circle. But now the direction of the moving air is just the opposite of what it was during the day. The warmer air over the water is pushed up by the cooler air coming from the land.

There are always warm spots and cold spots on the earth. The air above becomes warm or cold from the spots beneath it. Cold air moves toward the warmer air and pushes it upwards. This explains why there are always winds blowing somewhere.

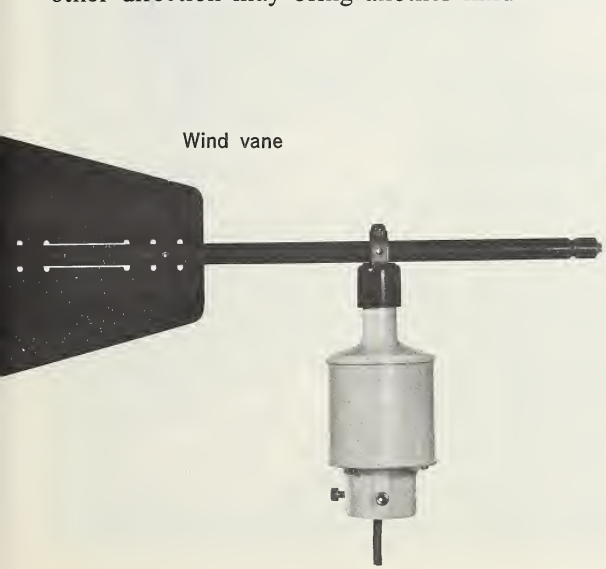
It is the sun's energy and the air around the earth, working together, that make the winds.

Why Wind Direction Is Important

When scientists forecast the weather, they need to know about the wind. Winds from one direction may bring one kind of weather. Winds from another direction may bring another kind of weather. Knowing the direction of the wind helps weather scientists forecast the weather. Knowing how fast the winds are moving helps these scientists tell how soon the weather is likely to change.

Weather scientists have an instrument to measure the speed of the wind. This instrument is the **anemometer** (an-uh-MOM-uh-ter).

The anemometer in the picture has cups that turn a rod when the wind blows against them. The speed with which the rod spins is recorded on a dial. In this way the weather scientist knows how many miles an hour the wind is blowing



Wind vane

Anemometer

Finding Wind Direction

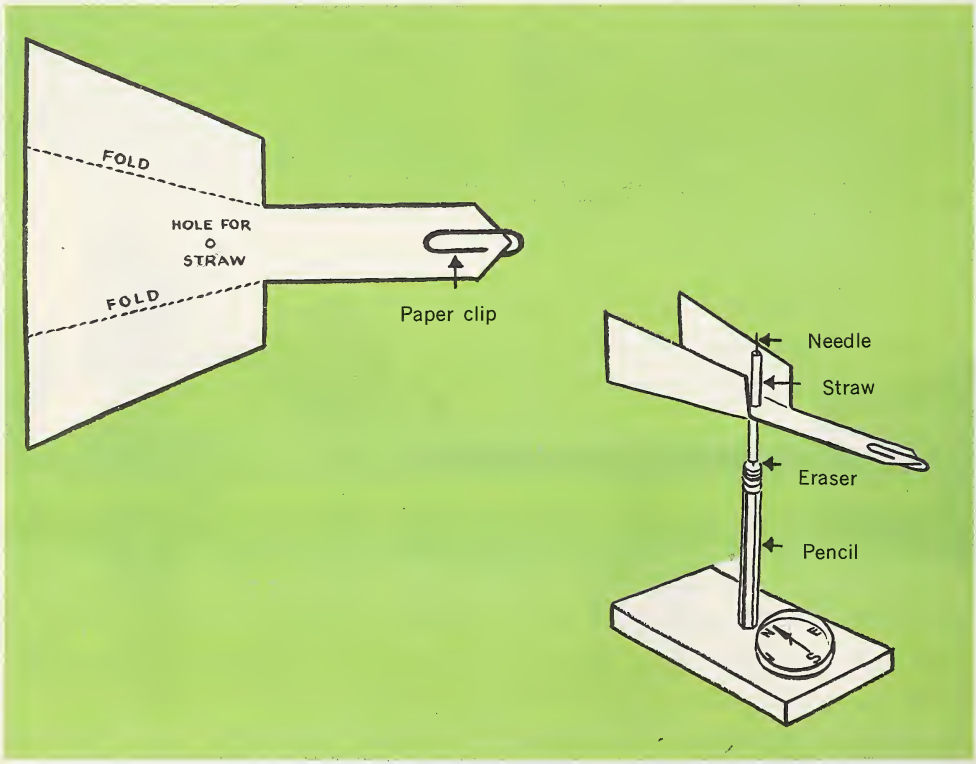
The **wind vane** or weather vane is an instrument for finding the direction the wind is coming from.

The picture shows you how to make a simple vane. Use heavy cardboard. The kind used for shoe boxes is good. Make all the holes small, so that everything will fit tightly. Be sure that the turning point is at the right place for the vane to swing freely.

You will need to place your wind vane away from anything that might block the wind.

Using a compass, place the box so that the **N** points to the north. When the wind blows, the pointer of the vane will point in the direction from which the wind is coming.

A wind that comes from the south is called a south wind. A wind from the north is called a north wind.



Using What You Have Learned

1. You can tell about how fast the wind is blowing by watching your school flag. Below, you will see a chart that tells you how the wind affects a school flag.

Flag hangs limp	Wind less than 4 mph
Flag flaps occasionally	Wind 4 to 7 mph
Flag waves	Wind 8 to 12 mph
Flag stands out from pole	Wind 13 to 18 mph
Flag pulls rope with it	Wind 19 to 24 mph
Flag snaps as it flaps	Wind 25 to 31 mph
Flag must be taken in	Wind more than 31 mph

2. Pick a committee to make a special exhibit or a scrapbook called "Weather in the News." The committee should keep daily records of the weather and cut out the weather maps from the newspaper. The committee should also look in the newspapers to see if they can find stories about how the weather has affected people.

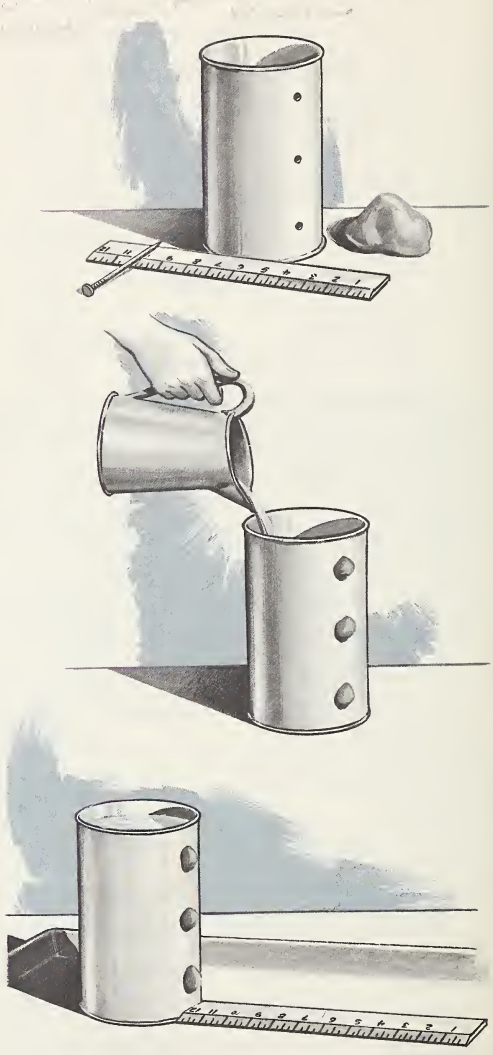
3. You can find out what would happen if air could not press down on the water in a glass. Cut off the end of a balloon. Then take the balloon and pull one open end down over the neck of a small bottle filled with water. Fasten the balloon tightly to the bottle with a rubber band. Then slip a glass tube through the other end of the balloon, and fasten this end tightly around the tube with a rubber band. Now suck through the tube. What happens?

How Air Acts

You already know that air has weight. This means that gravity pulls air toward the center of the earth.

When you pile things higher and higher, the weight, or downward push, at the bottom becomes greater. Suppose you piled books one on top of another on a scale. The more books you put on, the heavier the push against the scale would become.

You can see how this works with water. Water often acts much like the air. Take a quart juice can. Punch three holes at the side of the can: one hole near the bottom; one hole above it, halfway up; and a third hole near the top. Plug each hole with modeling clay. Fill the can with water. Put a 12-inch ruler alongside the can. Remove the lowest plug. Measure the distance the water shoots out. Return the plug to the hole. Refill the can with water. Next, pull out the middle plug and measure the spurting water. Return this plug to the hole and refill the can with water again. Now remove the top plug of clay and observe what happens. From which opening did the water shoot the farthest? From which



What will happen as you pull out each plug?

the least? At which opening was the pressure of the water greatest? Why?

Air is not solid, like books. Nor is it a liquid, like water. You cannot squeeze water molecules much closer together by pressing on them. But when you press down on air, you squeeze the molecules of air closer together.

It is a little like making a big pile of hay. The more hay you throw on the pile, the more gravity pulls on it and the more the hay pushes down. The hay at the bottom is packed closer together by the weight of the hay above.

High up in the air, or at the top of a mountain, the molecules in the air are not packed so closely together as they are farther down. The air that fills a gallon or a quart bottle near the earth is heavier than the same amount of air higher up. Air gets lighter as you move away from the earth.

With a crayon or piece of colored chalk, draw a square an inch on each side on the back of your hand. Now try to imagine a column of air reaching up as far as there is air. Scientists believe the column would have to be at least 700 miles high. If you could weigh the column of air touching one square inch of your skin, it would weigh almost 15 pounds. "Almost 15 pounds" is the way we express the pull of gravity on the air in that imaginary column. You can see that the weight or pressure of air on your whole body is very great. The air pressure at any spot on the earth is the pressure of the air above that spot.

You do not feel the weight (almost 15 pounds for each square inch) because it presses on all sides of your body. If it did not press equally on all sides, you would cave in. Sometimes, when the air pressure around you suddenly changes a great deal, you can feel the change in your ears.

Perhaps you have gone up in an airplane, or in a car to the top of a high mountain, or in an elevator to the top of a very tall building. Do you remember feeling the sudden change in air pressure in your ears?

Weighing Air

The weight, or pressure, of the air changes. It changes as you climb a mountain or go up in an airplane. It changes as the air is heated by the earth. It changes when the air loses some heat and becomes cooler. When

air pressure changes, it usually means the weather will change. Weather scientists measure air pressure to help them predict the weather. They have instruments to measure air pressure. Any instrument used for measuring air pressure is called a **barometer** (buh-ROM-uh-ter). Now you will find out how a barometer works.

When the glass on page 231 was lifted slowly out of the pail of water, the water stayed in the glass. The air pushing down on the water in the bucket held it there. You could try a taller glass, and it would still work. You could keep trying taller and taller glasses, and it would still work. It would work until you had a glass 34 feet tall. Then some of the water would fall out of the glass.

If you were a giant and you had a glass 35 feet tall, you could try it out in a lake. If you did this, you would find that air pressure at sea level would hold the water only up to about 34 feet. In other words, the weight of the air, and the weight of 34 feet of water in the glass, balance each other.

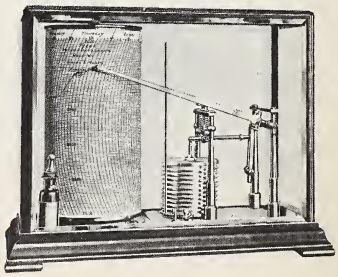
If the air pressure were less, some of the water in your giant glass would drop out.

Of course, such a tall glass would be very difficult to use. So instruments for measuring air pressure use a liquid heavier than water. With a heavier liquid, we can use a shorter tube. It has been found that a good liquid to use is *mercury,* because it is 13 times heavier than water. At sea level the weight of the air will push mercury about 29 or 30 inches up the tube.

A barometer that uses mercury is called a **mercury barometer.** We read the barometer by noting how many inches the mercury is pushed up in the tube. In this way, weather scientists

A typical mercury barometer used by the United States Weather Bureau.

The type of barometer below, called a barograph, records air pressure changes on paper. A pen fastened to the arm writes on the paper as the drum turns.



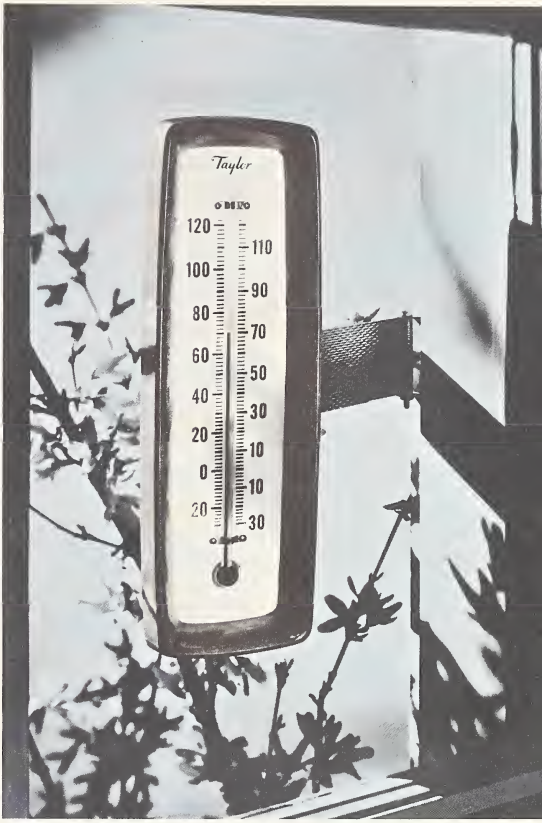
can compare pressure changes from day to day, or even from hour to hour. When the weather scientist says the barometer reading is 30, he means that the mercury is 30 inches high in the tube. Does this mean that the air is pressing hard, and that the pressure is high?

Measuring the Air Temperature

How do you know what to wear to school? Usually you listen to the weather forecast on the radio in the morning. You listen especially for the temperature. If the temperature is in the 30's, you wear warm clothes. If the temperature is in the 80's, you dress lightly. A **thermometer** is used to measure the temperature.

It is hard to make a thermometer, but you can learn how thermometers work. You know that air is made of very small parts called molecules. You also know that when air is heated its molecules move faster and farther away from each other.

Liquids are also made of tiny molecules. Molecules of liquid are packed much more tightly together than air molecules. They cannot move as freely or as far apart as air molecules.



What happens to the height of the column of liquid in the glass tube as the temperature of the air rises and falls?

When a liquid is heated, its molecules start to move faster. They spread farther apart, too. They take up more space.

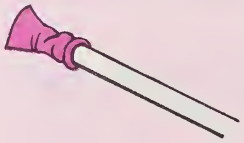
What Happens When a Liquid Is Heated?

What You Will Need

small bottle	glass drinking tube	rubber band
balloon	adhesive tape	scissors

How You Can Find Out

1. Cut the neck off a balloon.
2. Slide a glass drinking tube through the part of the balloon which you have cut off.
3. Fasten the neck of the balloon tightly to the drinking tube with a rubber band.
4. Fill a small bottle to the top with water and then stretch the balloon over the mouth of the bottle.
5. Put a little more water in the glass tube and mark the water level with a piece of adhesive tape.
6. Heat the water in the bottle by placing it in very hot water.



Questions to Think About

1. What happens as the water in the bottle becomes hot? Can you explain why this happens?
2. What happens when the water in the bottle cools?

Thermometers usually have mercury or alcohol in the glass tube instead of water. When the mercury is heated by the air, the molecules in the mercury move faster and farther. They take up more room. But there is no place for them to go except up in the tube.

The **scale** on the tube shows how far up the tube the mercury reaches. The marks on the scale are called **degrees.**

Some thermometers are marked with the **Fahrenheit** (FAR-un-hyt) scale. On the Fahrenheit scale, water freezes at 32 degrees. This is written 32° F.

Water in the Air

On page 224 you read how the weather is affected by changes in the air. You have read how changes in the temperature and pressure of the air cause winds. The amount of water in the air also affects our daily weather in many ways. And so, the weather scientist needs to know about water in the air as much as he needs to know about air temperature and air pressure.

Without water in the air, there could not be fog or mist or clouds. There could not be rain or snow.

How Water Gets into the Air

Water molecules, whether they are in great bodies of water or in small puddles, are always moving, but not all at the same speed. There are always some molecules moving faster than others. Some move fast enough to escape from the surface of the water into the air.

These runaway water molecules move in among the air molecules. Then they are called water vapor. The escape of water molecules into the air is called **evaporation** (ih-vap-uh-RAY-shun). Other liquids can evaporate too.

As water is cooled, its molecules move slower and slower. They move shorter distances. Evaporation is slow.

As water is heated, the molecules move faster and faster. They move greater distances. Evaporation is fast.

The water molecules at the top of a container escape first. Those at the bottom cannot escape because the molecules above press down on them. The larger the surface of the water, the more molecules escape.

Do you see why the same amount of water will evaporate more slowly from a full cup than from a pie plate?

How Water Gets Out of the Air

If water did nothing more than evaporate, soon all the water on the earth would evaporate into the air. All the earth's water would become water vapor. There would be no water for plants and animals. Plants and animals could not live.

But water vapor can come out of the air as well as go into it. When water vapor changes to a liquid again, we call it **condensation** (kon-den-SAY-shun). Condensation is the opposite of evaporation.

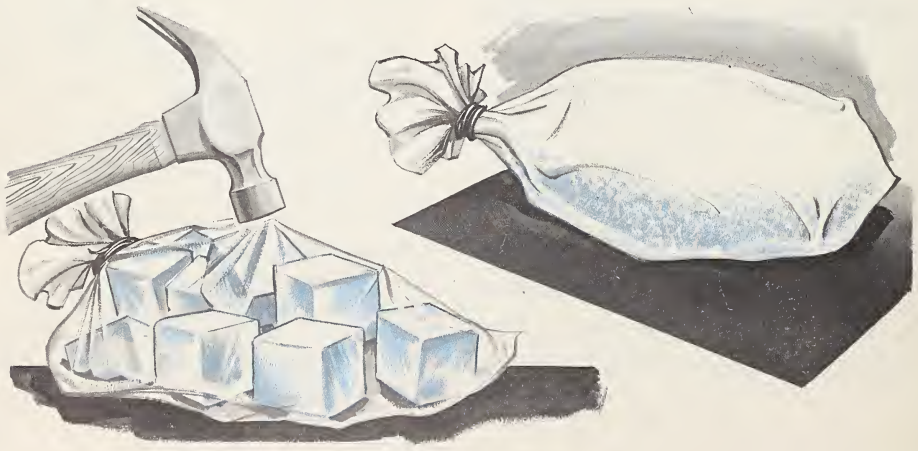
You can make some good guesses about how water condenses if you can remember how water gets into the air. Water molecules have to move very fast in order to get into the air. Anything that slows them down will cause them to come closer together. Then they will change back into water again.

Heating makes molecules move faster. Cooling makes molecules move slower. Condensation is caused by cooling.

Clouds

Clouds are made from tiny drops of water or bits of ice. You know that both water and ice are colorless. Then why do clouds sometimes look white? To see why clouds appear to be white, try this. Get a clear ice cube or some pieces of ice. Put it into a bag

Crush the ice with a hammer. What is the color of the crushed ice?



and crush it with a hammer. The colorless ice, now in many pieces, looks white.

Whenever you crush an ice cube, you break its six smooth surfaces into many tiny pieces, all facing in different directions. The light striking all these surfaces is scattered in all directions and makes the colorless ice look white.

The water droplets and the ice crystals in the clouds scatter the sunlight in the same way.

Rain and Snow

Steam is very hot water vapor. You remember that you cannot see steam. Boil some water in a kettle. Is there a little distance between the white cloud that is formed and the spout of the kettle?

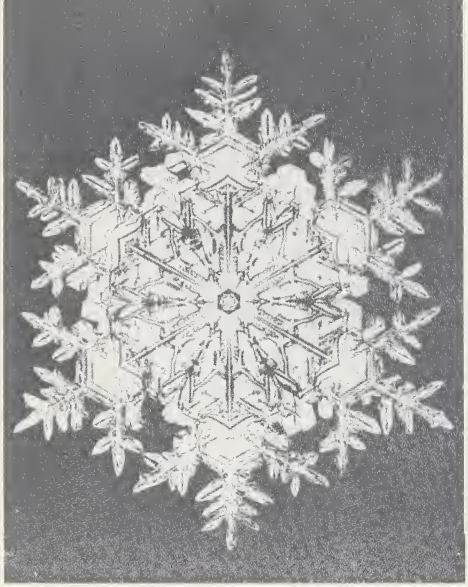
The steam is in the space between the spout and the little white cloud. The cooler air away from the spout cools the steam. The water molecules are slowed down by the cooling. When they slow down they come closer together. They condense. The cloud is really tiny drops of water floating in the air.

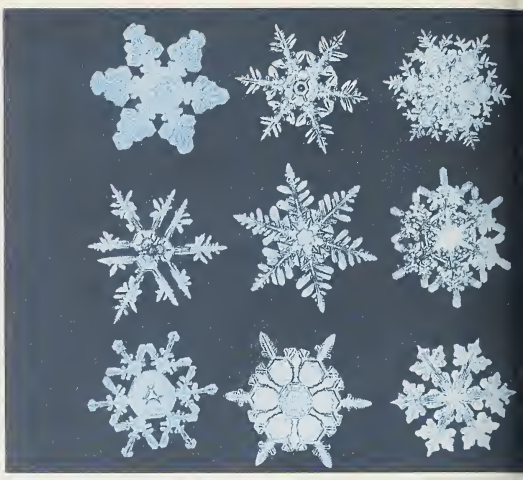
Hold a cold plate so that the steam strikes it. The cold plate makes the steam condense much faster. The tiny drops of water come together and make big drops of water. They fall from the plate like rain. But real rain is not quite so easy to explain. Not all weather scientists agree as to how rain and snow are made high in the air.

Scientists think that water will not condense unless there is something on which it can condense. But on what could water vapor condense high in the air?

Many scientists think that water vapor condenses on tiny particles of dust in the air. Then the vapor collects into tiny drops of water and forms a cloud.

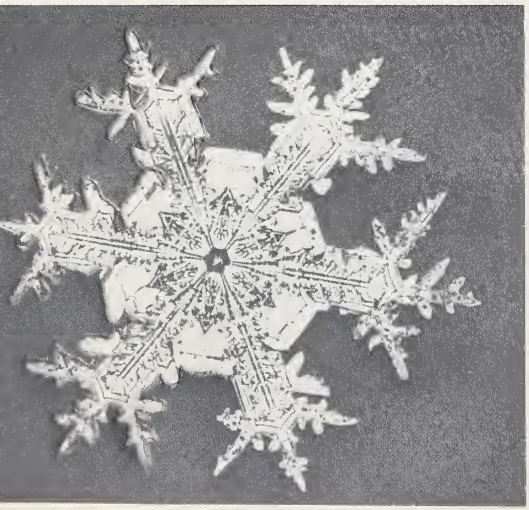
How does this demonstration give you an idea of the way in which rain is formed?





SNOWFLAKE PATTERNS

When the temperature of the air high above the earth is 32° F. or below, the moisture in the air forms snow. Snowflakes are bits of material formed in special patterns. How are all the patterns alike? How are they different?

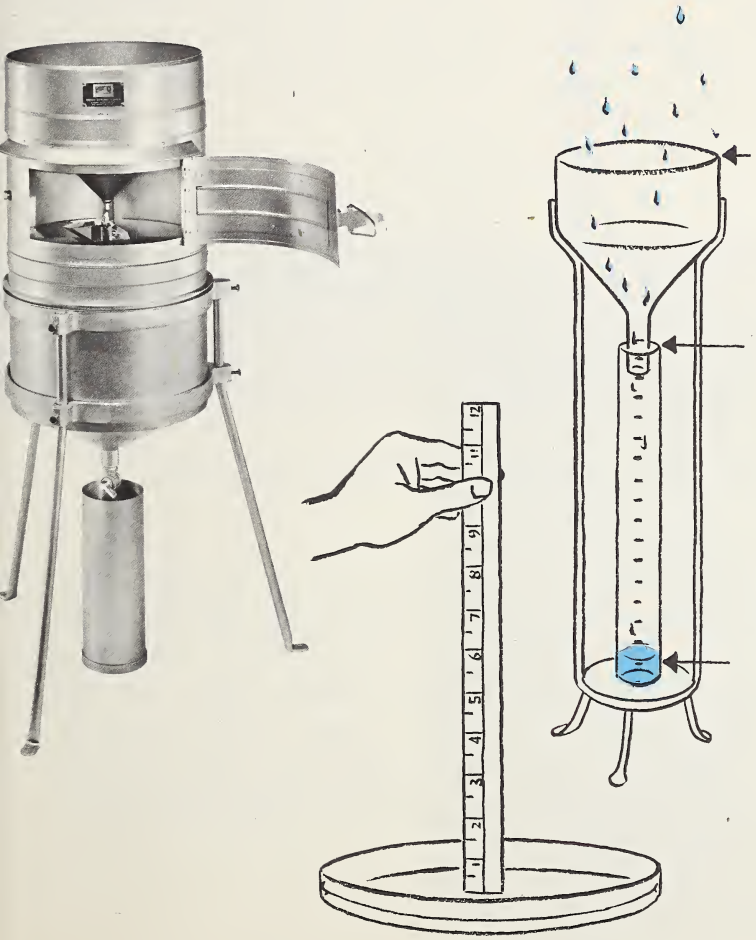


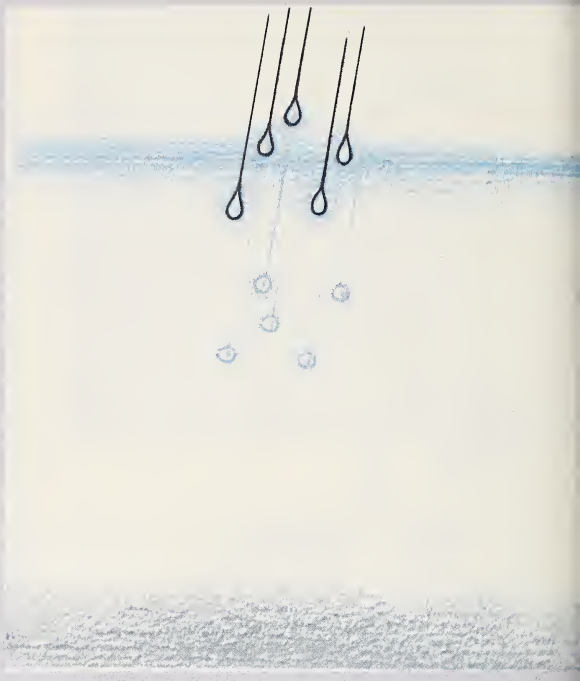
Scientists can measure the amount of rain that falls. They do this with a *rain gauge*. You can make a simple rain gauge. Take a pan with straight sides and put it outside while rain is falling. Then, using a ruler, measure how deep the water is in the pan.

At weather stations there are rain gauges that measure very light rains. You can see one in the picture.

There are many reasons why we need to measure the amount of rain and snow that falls. What reasons can you think of?

Here you see the weatherman's rain gauge and one that you can make.





Read the text first. Then look at the pictures. Can you now explain, using the pictures, how hail and sleet are formed? What is the difference between the two?

Hail and Sleet

Sometimes frozen raindrops are blown back up into a cold layer of clouds. Other drops of very cold water freeze around the raindrops. Each time this happens, a new layer of ice is added. They get larger and larger and fall to the ground as hailstones. The diagram above, left, shows how this happens.

Sleet is formed when rain falls through air that is below freezing. The rain freezes into small bits of ice. The diagram above, right, shows this.

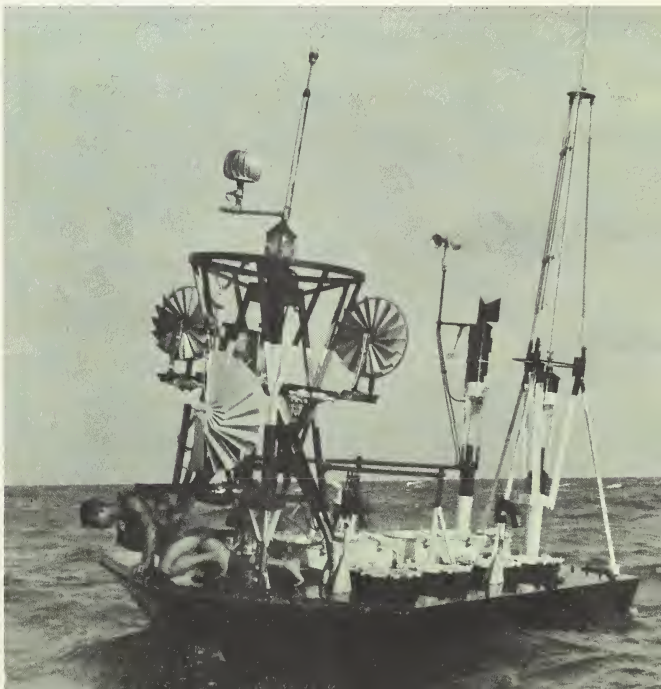
A Look at the Weather Scientist

We can tell many things about the weather just by our senses. We can tell when the wind is blowing, and when the air is still. We can tell when the air is cold, and when it is warm. We can see the clouds in the sky.

But just using his senses is not enough for the scientist. Like anyone else, he can see whether it is raining. But if he wants to know how much it has rained, he needs to take measurements.

In the same way, he measures and compares to find out more about the temperature of the air and the pressure of the air. He measures and compares to find out about the wind. He can measure how much rain or snow falls to the earth. He then compares these measurements with past measurements.

Weather scientists not only measure and compare weather conditions. They also keep careful records of their measurements and comparisons over the years. From these records they have found that certain kinds of weather usually come in the same order every time. Knowing this helps them tell what the weather will probably be tomorrow or the next day.



This weather station takes readings at sea. Why are such readings important?

Using What You Have Learned

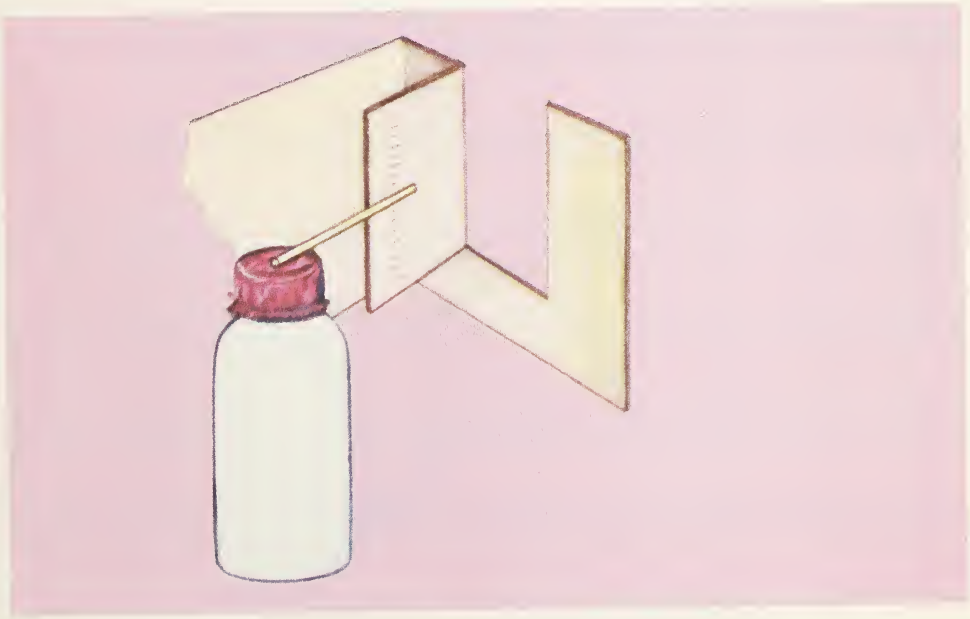
1. You can make a cloud in your classroom. You will need a large glass jar with a rubber cap. Some water and some smoke will also be necessary.

   To make your cloud, you put the water into the glass jar. Then put in the smoke. Cover the jar with the rubber top and then pull it up. When you do this, a cloud will suddenly appear. Can you explain why this happens?

2. You can make a barometer. The kind you will make is called an aneroid barometer. Can you find out why it is called by this name? Stretch a rubber balloon over the top of a glass jar and put a rubber band around the balloon to hold it tight. Glue a drinking straw to the center of the balloon top. This is your pointer.

If the air pressure on the outside of the jar becomes greater than that inside the jar, the balloon will be pushed into the jar and the point of the straw will rise. If the pressure of the air on the outside of the jar becomes less, the air inside will push the balloon up, and the point of the straw will go down.

To make a scale for your barometer, draw a line on a piece of paper. Put the paper so that the pointer will move up and down the line. At the same time each day, mark the spot the pointer points to. Keep a record of the changes in air pressure. Changing air pressure usually means changing weather. Your barometer will not be as exact as one you might buy. Still, it will give you some idea of how much the air pressure can change from day to day.



WHAT YOU KNOW ABOUT

Weather in Your Life

What You Have Learned

Telling the weather ahead of time is known as **forecasting** the weather. Weather forcasting is done by weather scientists working in **weather stations** throughout the world. Weather scientists know about the changes in **temperature, air pressure,** and **water vapor** in the air, and what causes these changes.

One of the reasons weather is different in various places is that sunlight heats some surfaces faster than others.

The speed and the direction of air often tell weather scientists what sort of weather to expect. An **anemometer** is used to find wind speed, and a **wind vane** is used to find the direction of the wind. A **mercury barometer** is used to measure air pressure. It is read by noting how many inches the mercury moves up or down in the tube. A change in pressure usually indicates that there will be a change in the weather.

Most important, weather scientists keep accurate records of all their readings. They use these readings to make comparisons. The comparisons help them to forecast the weather.

Checklist of Science Words

Here are some science words you read about in this unit. Can you tell what you have learned about each one?

anemometer	evaporation	thermometer
barometer	forecast	water vapor
condensation	molecules	weather station

Complete the Sentence

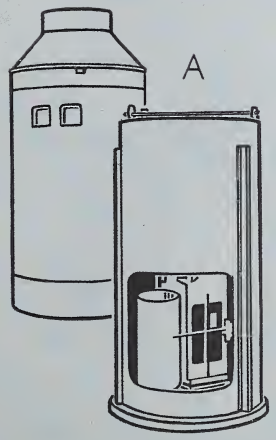
Write the numbers 1 to 4 in your notebook. Next to each number, write the word *faster* or *slower* to make the sentence correct.

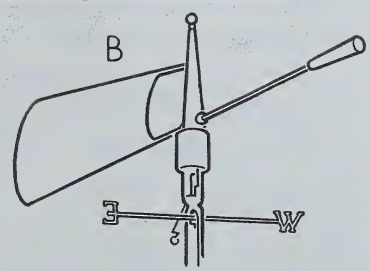
1. The land heats up ____?____ than the water.
2. Molecules of cold air move ____?____ than molecules of warm air.
3. Light-colored objects usually heat up ____?____ than dark-colored objects.
4. As water is heated, the molecules move ____?____.

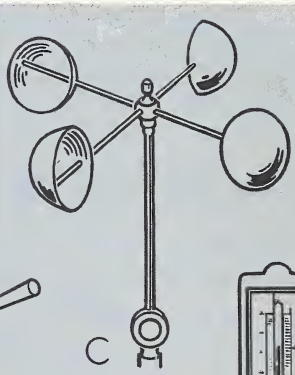
Find the Picture

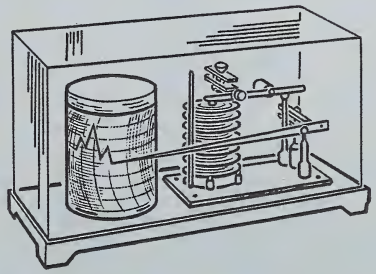
Write the numbers 1 to 5 in your notebook. Next to each number, write the letter that tells which picture the sentence is about.

1. It measures the speed of moving air.
2. It measures air pressure.
3. It measures the temperature of the air.
4. It measures the direction of the wind.
5. It measures the amount of rain that falls.









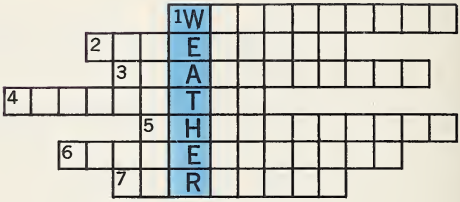
YOU CAN LEARN MORE ABOUT

Weather in Your Life

What Are the Words?

Write the words in your notebook.

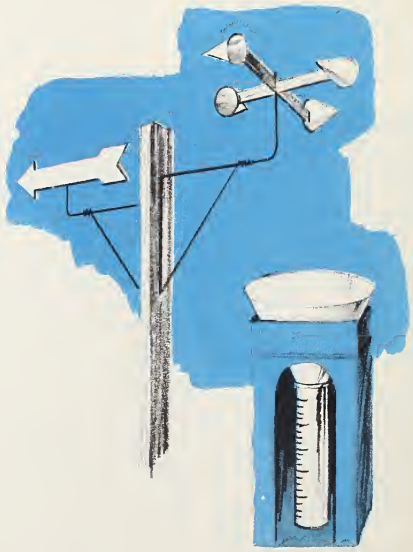
1. What water in the air is called.
2. The very small parts that the air is made of.
3. The changing of liquid water to water vapor.
4. It measures air pressure.
5. It measures air temperature.
6. What water vapor changing to a liquid is called.
7. To tell the weather ahead of time.



Build Your Own Weather Station

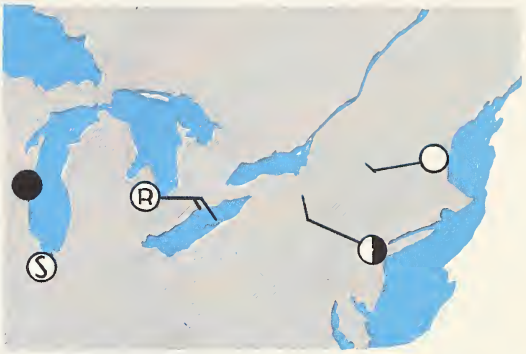
You can make your own records of the weather. You will need instruments to help you. To start your weather station, you can use the barometer you made. (Look on p. 254.) You can learn how to build other instruments if you read *Everyday Weather and How It Works* by Herman Schneider.

Make a record of your observations twice a day. Then see if you can forecast the weather. Compare your forecast with that of the weatherman.



How to Read a Weather Map

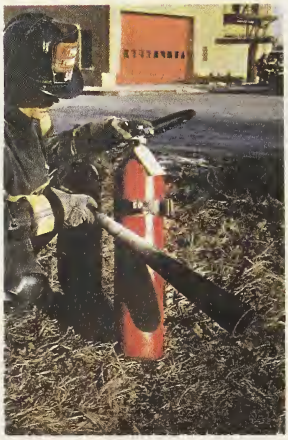
Below you can see some of the symbols that are used on a weather map and what they mean. Look at the map and see if you can tell what kind of day it is and how windy it is in the cities shown.

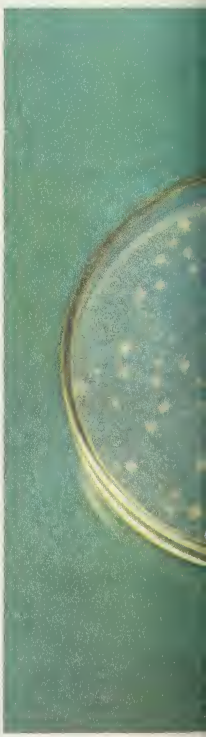


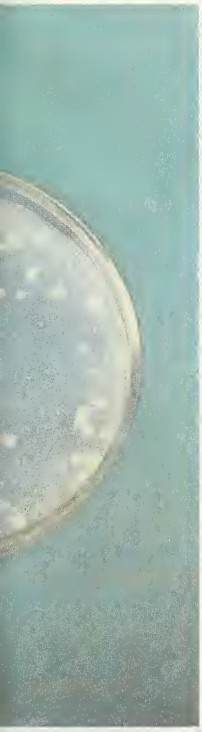
Clear	Calm
Partly cloudy	3-8 mph
Cloudy	9-14 mph
R Rain	15-20 mph
S Snow	21-25 mph

You Can Read

1. *Man and Weather Satellites* by Walt Disney. How satellites will aid in forecasting the weather.
2. *Exploring the Air Ocean* by Frank H. Forrester. How man learned about the weather.
3. *Weathercraft* by Athelstan F. Spilhaus. How to make and operate weather instruments.
4. *Let's Go to a Weather Station* by Louis Wolfe. The story of a trip to a local weather station.
5. *The First Book of Weather* by Rose Wyler. Tells what causes weather. Also, many experiments.







9

Safety and Science

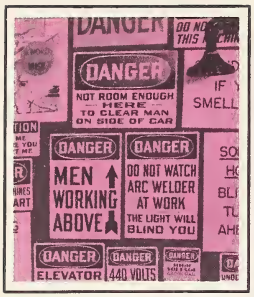
How Do Accidents Happen?

Bicycle Safety

Water Safety

Fire Safety

Safety in Science



In the gymnasium of one school, a sign reads: "Sneakers Must Be Worn While Playing in the Gym." Mr. Brownlee, the teacher in charge, makes sure that this rule is obeyed, because he knows that pupils with leather-soled shoes may slip on the gym floor and get hurt. Mr. Brownlee wants to avoid accidents.

How Do Accidents Happen?

Each year, the National Safety Council publishes a report called *Accident Facts*. The report tells about the kinds of accidents people have and where these accidents happen. It is important to know these facts. They are useful in finding ways to reduce accidents. But there are other things we need to know to prevent accidents. We must know *why* accidents happen. Then we can decide what we must do to remove the causes of accidents.

Children have accidents most often when they are playing. You can make your playtime safer if you follow three steps.

The first step is to *find out what causes accidents.* The second step is to *plan ways to avoid these causes.* The third step is to *use your plan to make your playtime a safer time.*

Can you make up a plan to prevent some of the accidents that might happen while playing? If you are careful during playtime, you are less likely to have accidents.

Children's Playtime

Where do you play? What do you play? What things do you use in your play?

You know what your answers to these questions are. But do you know what your classmates would answer? You can find out by making a survey.

Have each pupil write his or her name at the top of a sheet of paper. Ask each pupil to answer all three questions. More than one answer can be given for each question.

After everyone has finished writing the answers, the class should choose a

committee to write down the results. The committee should make a checklist like the one on page 264.

Have a member of the committee write each of the answers from the first pupil's paper on a separate final sheet of paper. This sheet is called the *master list*. After each of the answers from the first pupil's paper is written on the master list, a mark, |, is made to show that the first pupil listed it. Now read the answers from the next pupil's paper. If an answer appears on the second paper that has already been put on the master list, another mark, |, should be made after it. There are now two marks after this answer on the master list. If a different answer appears on the second paper, it should be written on the master list and a mark, |, made after it. The committee should add all the answers from everyone's paper to this list in the same way.

These are just a few of the many safety signs used by one large company. How do such signs aid the people who work for this company? Have you ever seen such signs?

DANGER
CRANE OVERHEAD
CAUTION MEN WORKING OVERHEAD
ONLY AUTHORIZED PERSONS PERMITTED TO OPERATE EQUIPMENT IN SHOP
SOUND HORN BLIND TURN AHEAD
DO NOT ENTER WITHOUT SAFETY GLASSES
NEVER RUN PUMP DRY
MEN WELDING DO NOT LOOK AT ARC
CAUTION DO NOT ENTER WHILE MACHINERY IS IN MOTION
FOR SAFETYS SAKE WALK UP & DOWN STAIRS
DANGER NO OPEN LIGHTS
NO SMOKING ALLOWED
DANGER EXPLOSIVE CHEMICALS STORED HERE
DANGER NOT ROOM ENOUGH HERE TO CLEAR MAN ON SIDE OF CAR
ALARM IF YOU SMELL FUMES
DANGER MEN WORKING ABOVE
DANGER DO NOT WATCH ARC WELDER AT WORK THE LIGHT WILL BLIND YOU
SOUND HORN BLIND TURN AHEAD
DANGER ELEVATOR SHAFT
DANGER 440 VOLTS
DO NOT USE THIS MACHINE WITHOUT PROPER AUTHORIZATION
ACID HAZARD WEAR HAT AND GOGGLES
CAUTION CONSTRUCTION WORK AHEAD
DO NOT ENTER WITHOUT SAFETY GLASSES
SAFETYS SAKE WALK & DOWN STAIRS
WEAR GOGGLES INSIDE RED LINES
GOOD HOUSEKEEPING
KEEP FROM UNDER CRANE LOADS
CAUTION MEN WORKING OVERHEAD
KEEP GATES CLOSED
CAUTION ELECTRIC TRUCKS GO SLOW
CAUTION TO PREVENT FIRE
ACID
NO SMOKING
FIRE BLANKET

MASTER LIST OF PLAY ACTIVITIES OF MISS DALE'S CLASS

1. Where we play:

swimming pool 𝍸 𝍸 𝍸	15
ice skating rinks or ponds 𝍸 𝍸	10
campgrounds |||	3
sidewalks 𝍸 𝍸 |	11
vacant lots 𝍸	5
backyard 𝍸 𝍸 𝍸	15
inside my home 𝍸 𝍸 𝍸 𝍸 ||	22
in the school playground 𝍸 𝍸 𝍸 𝍸 ||	22

2. What we play:

swimming 𝍸 𝍸 |	11
ice skating 𝍸 𝍸	10
camping |||	3
riding bicycles 𝍸 𝍸	10
baseball 𝍸	5
jumping rope 𝍸 𝍸 𝍸	15
checkers 𝍸	5
roller skating 𝍸 |	6

3. Things we play with or on:

water 𝍸 𝍸 𝍸	15
ice 𝍸 𝍸	10
camp equipment |||	3
bicycles 𝍸 𝍸	10
baseball and bat 𝍸	5
jump rope 𝍸 𝍸 𝍸	15
checker set 𝍸	5
roller skates 𝍸 |	6

The Causes of Accidents

Look again at the marks after the answers of Miss Dale's class. How is each fifth mark made? Why is it made this way? What do the numbers on the right tell us?

Not all the play activities of Miss Dale's class are shown. Your survey might show many more different kinds of activities for your class. What is your favorite play activity?

Have you ever had an accident? What is an accident?

An accident is a mishap. Usually we do not expect an accident to happen. It just happens! Do you think that every accident has a cause?

Think of an accident that has happened to you. Was there a cause for it? How could you have prevented this accident? Make up a rule about the way to prevent an accident.

Using What You Have Learned

Look over your survey. What things on your list do you think might cause accidents? From a survey of children's accidents in one large state, the following things were found to be related to accidents:

1. Sports equipment (baseballs and bats)
2. Bicycles and tricycles
3. Toys (chemistry sets, electric stoves, and electric irons)
4. Playground equipment (swings and seesaws)
5. Sharp-edged tools (chisels and screwdrivers)
6. Children's cars or wagons
7. Broken glass and tin cans
8. Animals (cats and dogs)

Have you ever been injured by any of these things? Children can be injured in different ways by accidents. Make another survey to find out how the boys and girls of your class were injured in accidents.

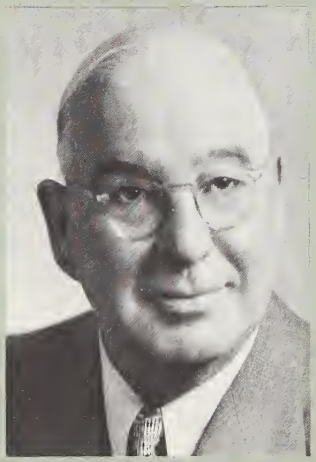
Bicycle Safety

How many pupils in your class have bicycles? How many have had accidents with them? What caused the accidents?

The National Safety Council estimated that bicycle accidents in the United States in 1964 killed about 650 people and injured 35,000 other people. Children between the ages of 5 and 14 accounted for two thirds of the people killed in bicycle accidents. It is easy to see from these numbers that bicycles can be very dangerous when people are not careful.

Collisions with cars, buses, and trucks were the most common bicycle accidents. Falling off bicycles, riding into trees and fences, riding into people, and racing were other causes of bicycle accidents. Still other accidents happened because a rider came out of a driveway, or entered the street from between parked cars, without looking.

Were you ever in a bicycle accident because you did one of these careless things? If you were, or if you know someone who was, you know how serious these accidents can be.



William Potts made the first four-way traffic-signal tower, shown on the left.

PATHFINDERS IN SCIENCE

William L. Potts

(1893–1956) United States

Imagine what it would be like if there were no traffic lights in your town. How would you know when to cross the street? How would automobiles travel safely along the streets?

As a member of the Detroit Police Department and as a traffic engineer, William L. Potts was faced with just such a problem.

Because of such surveys, rules like those on pages 268 and 269 were made. Can you think of the reason for each rule? Perhaps you can have a class discussion on the reasons for these rules.

Some schools have bicycle safety programs. In these school safety programs, young people learn how to use their bicycles safely. They find out what causes most bicycle accidents. Then they learn how to avoid the most common kinds of accidents. These school safety programs help greatly to reduce the number of serious bicycle accidents. Can you plan a bicycle safety program for your school?

In 1920, Mr. Potts set up the world's first four-way traffic-signal tower at Woodward and Michigan Avenues in Detroit, Michigan. To get attention, he chose the tallest policemen in the department to operate the tower. The tower had twelve lamps—three lamps on each of the four sides of the tower. One year later, in 1921, Mr. Potts saw another of his dreams come true. The first automatic traffic signal was built.

More than forty years have passed, and traffic signals have changed a great deal. But the original idea of traffic lights developed by William Potts is still being used.

William Potts made many important changes in motoring safety. He helped dozens of Michigan communities solve their traffic problems. He is also known as one of the first men to try using two-way radios in police cars. Now nearly every police car has a two-way radio.

"Old Mr. Traffic Tower," as Mr. Potts was respectfully and affectionately named by his friends of the Detroit Police Department, did much to make our world a safer place in which to live.

BICYCLE SAFETY RULES

1. Ride your bicycle in the same direction as the traffic is moving.
2. Ride only as fast as safety permits. Ride slowly on crowded or slippery streets.
3. Be careful not to zigzag in and out of moving traffic.
4. Give signals before making turns, and only after looking around to make sure nothing is coming your way.
5. Watch out for people in parked cars who may suddenly open one of the doors.

6. Look carefully before coming out of driveways or from between parked cars.

7. Watch out for parked cars that might suddenly speed into your traffic lane without warning.

8. Never race.

9. If you must ride at night, be sure your bicycle lights are working.

10. Never ride with another person on a bicycle unless the bicycle is built for two.

11. Always ride single file when you are riding with others—never two abreast.

12. Be careful! Ride safely!

Check Your Bicycle for Safety

In order to ride your bicycle safely, you must do more than obey all safety rules. You must check your bicycle regularly to make sure it is always in good condition. Study the picture below. It shows all the places that you should check on your bicycle. Remember that a small repair can often prevent a big accident.

A good safety measure for a person who uses his bicycle after dark is to have the bicycle painted a light color instead of a dark color. If you did the experiment on pages 14 and 15, you saw how different colors reflect different amounts of light. The experiment on the next page will also help you to understand why some colors are safer to wear at night.

Always Ride With Caution and Take Good Care of Your Bicycle

HANDLE GRIPS: Replace worn handle grips. Cement them on tightly.

SADDLE: Adjust to body and tighten all nuts.

WHEELS: Eliminate wobble. Tighten wheel nuts and oil bearings.

REFLECTOR: Must be visible for 300 feet.

COASTER BRAKE: Does it brake evenly? Unless you're an expert, have it adjusted by a serviceman.

CHAIN: Check for damaged links. Secure snug fit. Clean and lubricate frequently.

PEDALS: Lubricate and tighten pedal bearings and spindle. Replace worn pedal treads.

CRANK HANGER: Keep clean and greased. If it wobbles, have serviceman make adjustments.

WARNING DEVICE: Be sure it works properly.

HANDLE BARS: Adjust to body. Tighten and keep stem well down in fork.

FORK BEARINGS: Lubricate.

LIGHT: Must be visible for 500 feet.

SPOKES: Replace broken ones promptly.

TIRES: Inflate to correct air pressure. Remove imbedded metal, glass, cinders, etc.

TIRE VALVE: Inspect often for leaks.

Have Your Bicycle Checked Twice a Year By a Reliable Serviceman

Which Colors Are Safest to Wear at Night?

What You Will Need

flashlight colored paper (several sheets)

How You Can Find Out

1. The sheets of paper stand for the bicycle riders.
2. The flashlight stands for an automobile headlight.
3. Darken your classroom as much as possible.
4. Shine a flashlight on a dark sheet of paper.
5. Then shine the flashlight on a light piece of paper.
6. Compare several sheets of paper to see which color can be seen most easily.

Questions to Think About

1. Why is it safer to wear light-colored clothing when you are bicycling at night?
2. Why should you make sure that your bicycle has a taillight or a reflector?
3. What colors do policemen wear at night so that they can easily be seen?
4. Which of these colors do you think would be best for you to wear when you are bicycling at night?

blue	black	white	yellow
red	green	orange	purple

5. What colors do automobile makers use for different lights on a car to make them do their job at night? Why do you think car makers choose these colors?
6. Have you ever seen an airport at night? What color are the lights that are used along the runways? Why do you think this color is used?
7. White is the best color to wear for safety at night. What is the worst?

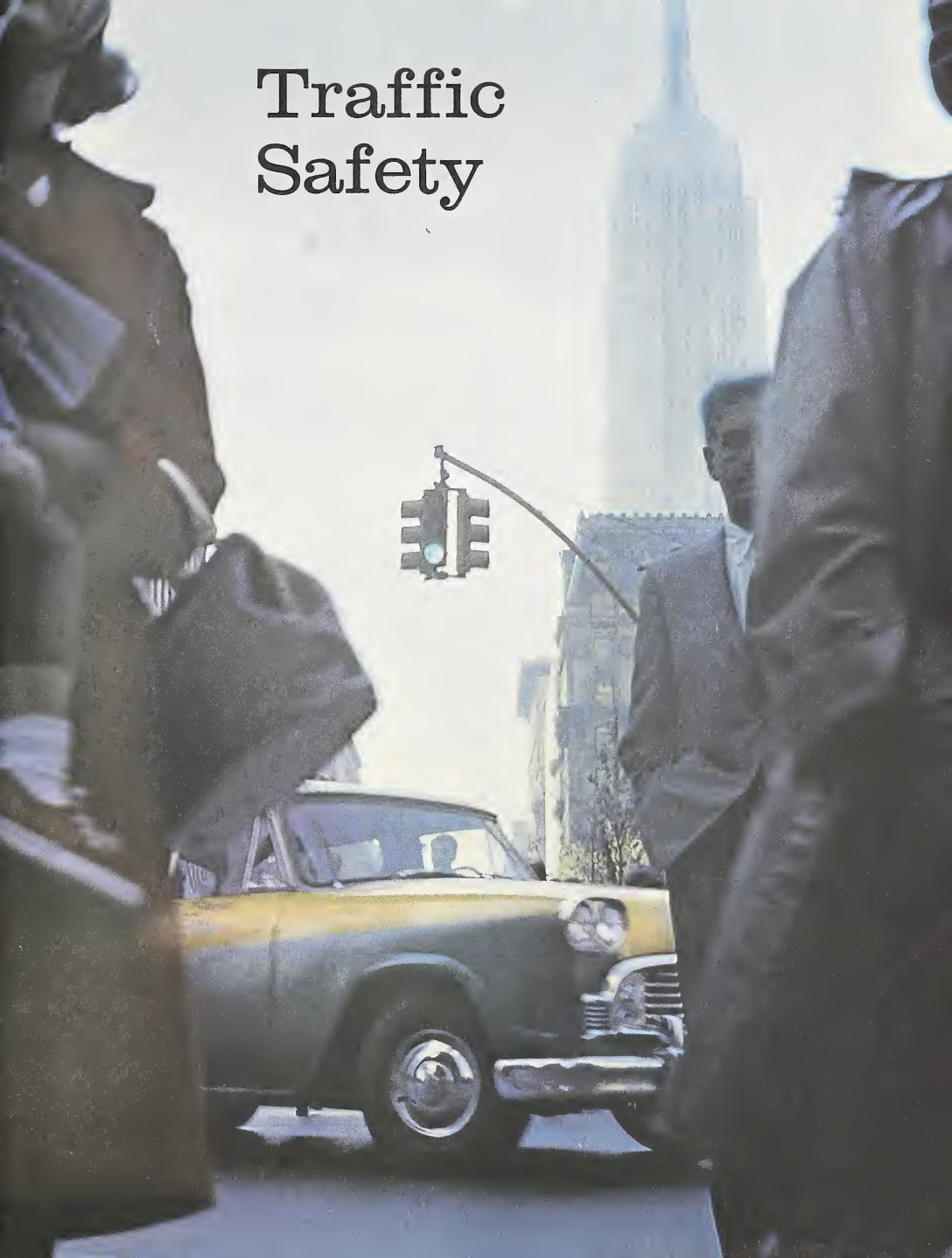
An automobile driver sees both you and your bicycle at night because the light from his headlights is reflected back to him from you and your bicycle. Light colors, such as white and yellow, reflect more light than darker colors, such as black and brown. For this reason, it is safer to wear light-colored clothing for riding at night. You should also be sure your bicycle has a red taillight or a reflector, as well as a headlight. And most important, ride at night only if it is really necessary.

ABOUT "TRAFFIC SAFETY"

Knowing about traffic safety is important for everyone. But it is most important for boys and girls who have not been crossing the streets by themselves or who have not been riding bicyles very long. One of the best ways to find out about traffic safety is by reading your schoolbooks and listening to your teacher and parents.

In some communities, the police department has a special safety education group, which, among its other duties, visits schools to talk about and demonstrate traffic safety. The New York City Police Department has specially trained policemen who do this. You will now see and read about a safety demonstration that took place at an elementary school.

Traffic Safety



Officer Washington talks to the pupils about traffic safety. He begins by having a policeman hold up different traffic signs.

Officer Washington points to the backs of the signs and asks who can identify the signs from their shapes and designs. Why is it important to be able to tell traffic signs from their shapes? Can you tell what the signs mean by looking at their shapes?

This sign has eight sides. It tells the motorist to come to a complete stop and not move forward until he is sure that it is safe.

This four-sided sign tells us there is a school crossing. There are two such signs used. One is square, and the other is diamond shaped. Which kind do you have in your community?

This is a yield-right-of-way sign, which means that the motorist must give the other traffic the right of way. All these signs are for motorists. But it is just as important for you to know about them. Can you tell why?

Here's how you signal a right turn . . .

signal a left turn . . .

The policeman is pointing to a headlight and taillight on the bicycle.

Why must you have these lights on your bicycle if you ride at night?

Officer Washington tells the boys and girls that more youngsters are injured crossing in the middle of the block than in any other kind of accident.

A motorist gives certain signals when he is stopping his car, making a right-hand turn, or turning to the left. If you ride a bicycle, you must also use signals. Can you tell why it is important for you to do so?

. . . signal a stop.

In 1964 in New York City, 2,382 boys and girls between the ages of 5 and 10 were injured crossing in the middle of the block instead of at the corner. Let's see what happens when you cross from between parked cars in the middle of a block. The policemen pick Laura, an average-sized fourth grader, to assist them. Laura and Officer Egan will step off the curb into the street.

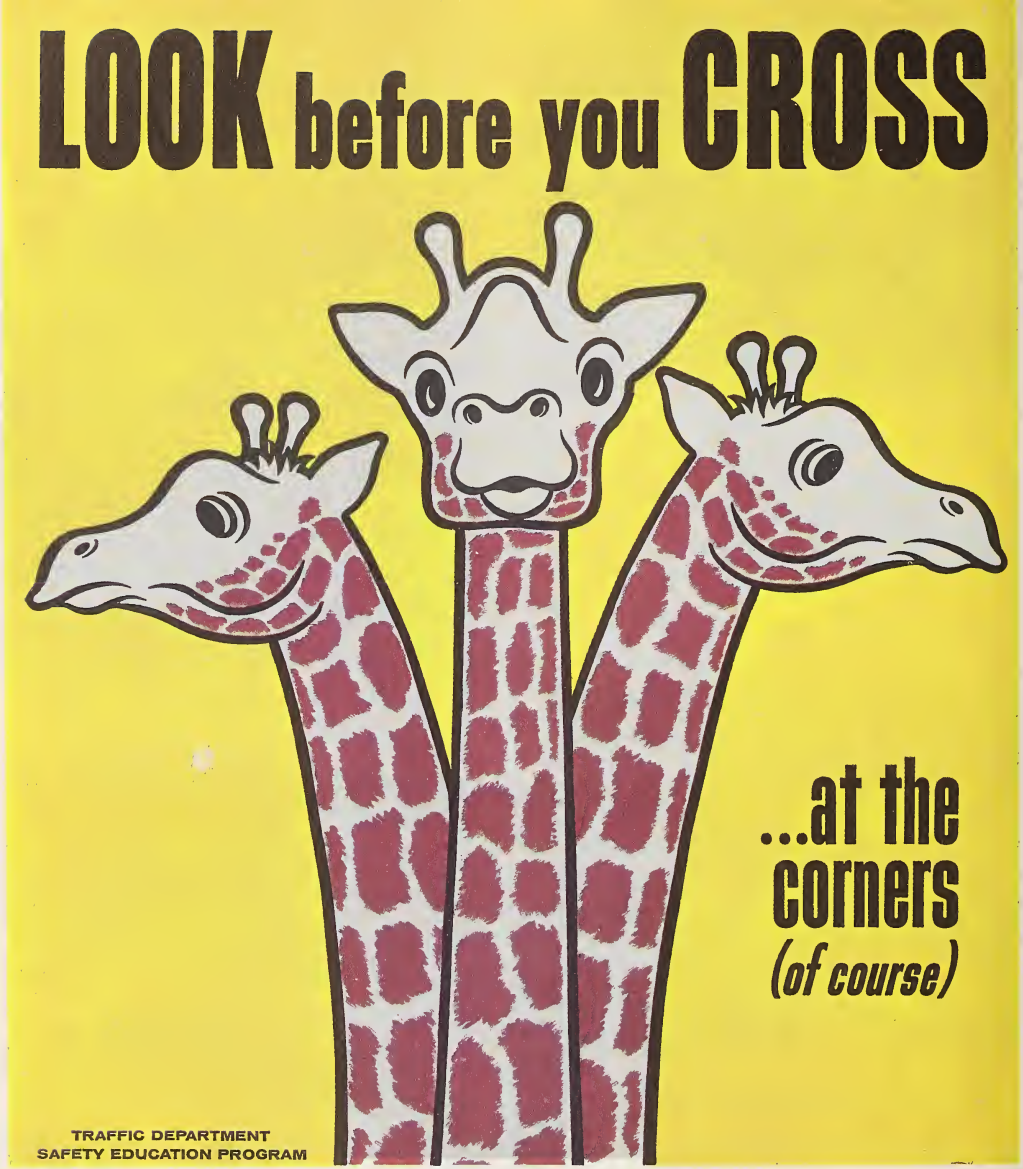
The police car coming down the street will stop when the driver first sees Laura. See how close the police car is to Laura.

Now a doll is put in the same place Laura was standing. This time the police car will be driven at 20 miles per hour. The policeman will put his foot down on the brake pedal of the car when he sees the doll.

The policeman puts the brakes on. But the car hits the doll! Why did this happen? The police car traveled a distance of 43 feet from the time the policeman observed the doll and applied the brakes.

You now see that a car cannot stop "on a dime." If you cross from between parked cars, the driver of the car may see you, but he may not be able to stop in time.

After seeing this demonstration, all the boys and girls promised never to cross mid-block, but only at the corners and only when they have a green light.



And that's the end of the Police Department's traffic safety demonstration. Promise you too will **always** be careful riding your bicyle and crossing the street.

Remember, safety is up to you!

Using What You Have Learned

1. Make a survey in your school to find the answer to these questions:

   a. In what grade do pupils ride bicycles most often?
   b. Where do the pupils in each grade ride their bicycles?
   c. How often do the pupils in your school have their bicycles inspected?

2. Make a plan for a school bicycle safety program. Where could you have it? Who would take part in it? Which adults could help you? Write to The National Safety Council at 425 N. Michigan Avenue, Chicago, Illinois, 60611, for their booklet on bicycle safety.

3. You could set up an Inspection Station for bicycles in your school. You may want to give a Safety Certificate to boys and girls whose bicycles pass inspection.

BICYCLE SAFETY LEAGUE

Membership Card

This certifies that Bike Owner .....

..... has pledged to observe all the Rules of Safe Riding and to keep his bicycle in good operating condition.

(Signed).....
(Safety Supervisor)

Water Safety

You know how important water is in our lives. We could not live without it. But water can also be dangerous if it is not used properly. Unsafe drinking water can make us very sick.

Water Pollution

More water is used now than ever before. There are twice as many people in the United States today as there were in 1900. More water is used today for irrigation and for industry.

Many lakes, streams, and rivers that once supplied water for homes and industry no longer do so. These waters are not safe to use. Factory wastes, garbage, and sewage have **polluted** (puh-LOOT-id) the water.

Waste materials from industry cause most of the water pollution. Yet people need the products of industry. The problem is to control pollution without stopping industry.

Making water safe is very expensive. In many towns sewage treatment plants treat the water to make it harmless before it is drained into a stream or lake. Scientists are looking for less expensive ways to get rid of wastes.

Water on Picnics or on Hikes

You are used to getting safe drinking water easily at home. But when you go on a hike or on a camping trip, you may sometimes forget that you cannot always find pure water away from houses and towns. You may forget that not all water is safe to drink.

In some states, signs tell where there is safe drinking water. Boy Scouts and Girl Scouts have helped in some of those places by collecting water samples. The water is tested by scientists to see if it is safe to drink. Scientists use special ways to find out if the water is safe. If the water is safe, signs are placed near the streams or springs.

Finding Out If Water Is Safe

Some water would not fool you at all. It looks muddy and dirty. Try to collect a sample of muddy water from a river or stream. Let it stand in a glass for a couple of hours. Then look at the bottom of the glass. What can you see? How can you get only the clear water into another glass? How can you find out how much mud is in the muddy water? Can you use what

you know about evaporation to find out?

Some water can fool you; it looks pure and clear. But you cannot tell whether water is safe just by looking at it. Sometimes clear water is not safe at all. If the water is not clean, **germs** can grow in it. Germs cause diseases. That is why impure water must be made pure before it is safe for you to drink.

You cannot tell whether water is safe by tasting it. Water from a mountain spring may taste different from the water in your home. It can taste different, and yet still be safe to drink.

The picture above shows the inside of a water purification plant. The picture below shows the aeration part of the plant. What does each of these sections have to do with making water safe to drink?

Do not waste water. Use only as much as you need. This is the way you can do your part to save water.

EXPERIMENT

Can Water Taste Strange and Yet Not Be Harmful?

What You Will Need

2 glasses of hot water ¼ teaspoon salt

How You Can Find Out

1. Fill two tall glasses with hot water.
2. Put one-fourth teaspoonful of salt into one glass, and stir it until you can't see the grains of salt.
3. Let both glasses stand until the water is cool.
4. Does the water look the same in both glasses? Taste the water in each glass.

Questions to Think About

1. Does the water from each glass taste the same?
2. Are both glasses of water safe to drink? How do you know?

How Can You Make Water Safe to Drink?

On a camping or hiking trip you may find yourself far from safe water. But you may be near a stream, a spring, or a river. In order to drink this water, you need to know how to make it safe. One easy way is to boil the water for about 20 minutes. This will kill the harmful germs in it.

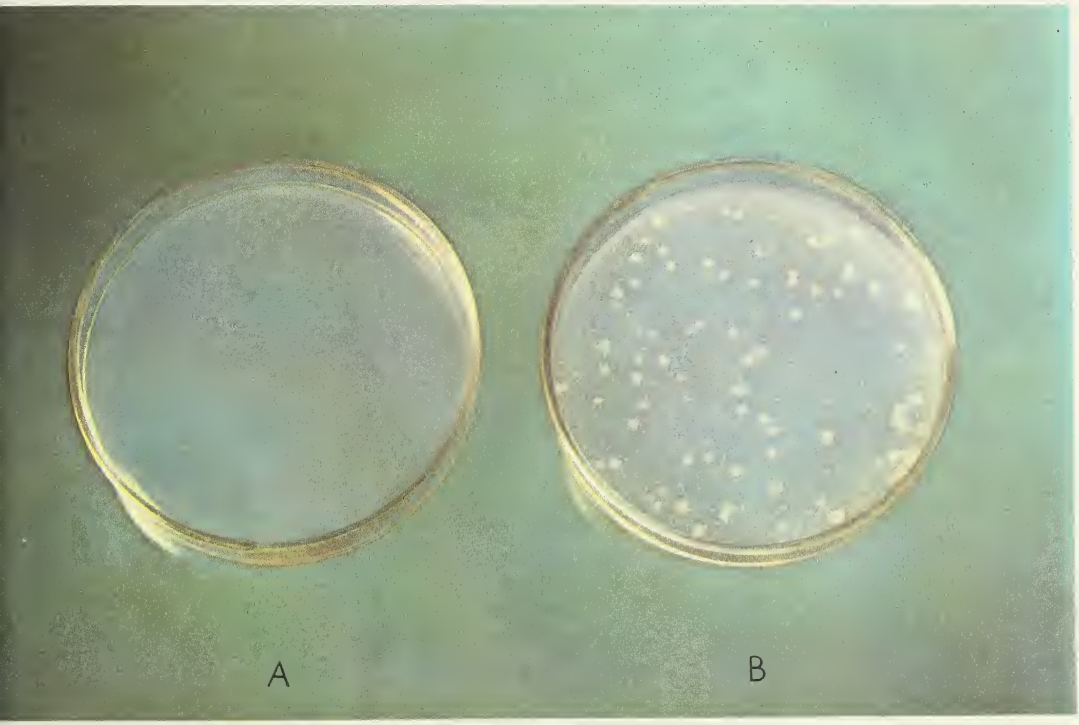
Look at the next page. It shows dishes of a special food where germs can grow. You do not need a microscope

to tell when germs are growing on these dishes. When the dishes are kept warm, the germs grow even faster. Soon there are so many germs that they make spots all over the dish.

Some water from a pond was put into two dishes. But the water had been boiled for 20 minutes before it was put into Dish A. The water had not been boiled before it was put into Dish B. Both dishes were kept warm for two days. Which dish has germs growing on it? What happens, then, when you boil pond water?

Boiling the water will not remove the mud, but there are ways of getting rid of mud in water. One way is to *filter* the water. You can do this by using a special kind of paper called *filter paper*.

What do you notice happening in Dish B, the dish with the unboiled water?



EXPERIMENT

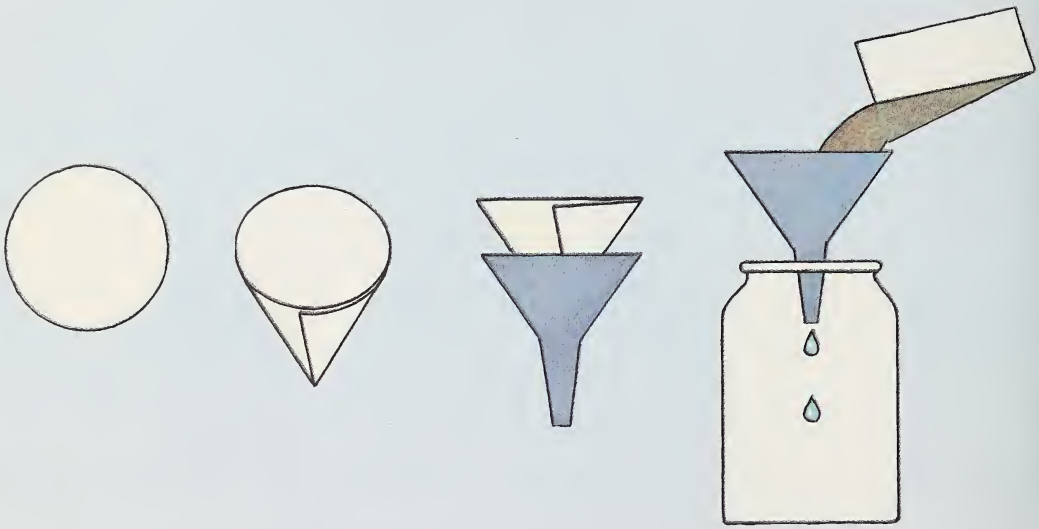
What Happens When Water Is Filtered?

What You Will Need

filter paper	funnel	glass jar
water		garden soil

How You Can Find Out

1. Put a piece of filter paper inside a funnel.
2. Place the funnel in the mouth of a glass jar.
3. Pour some water, with garden soil mixed in it, into the funnel.
4. Watch what happens to the soil. Look at the water in the jar. Does it look clean?



Questions to Think About

1. Do you think the water in the jar is safe to drink?
2. Do you think the water in the jar would be safe to drink if you boiled it for twenty minutes?

If you first filter and then boil the water from a stream or river, it will be safe to drink.

There is another way to kill the germs in water. You may have noticed that the water in swimming pools sometimes has a strong smell and makes your eyes burn. The **chlorine** (KLOR-een) in the water does this. Chlorine is put into the water to kill germs. Too much chlorine is not good for people. A very small amount of it is put into drinking water. Only enough chlorine is used to kill the germs. Many cities put chlorine in their drinking water to make the water safe to drink.

How Can We Get Pure Water?

You know that boiling kills germs. The germs remain in the water, but since they are dead, they are harmless. Water that has been boiled may be fit to drink, but it is *not* pure water.

Pure water has *no plants or animals of any kind in it.* It does not even have any minerals in it. To get pure water we have to make the water **distilled** (dih-STILD).

The first step in distilling water is to boil it. The dirt and minerals stay in the container, as they did when you boiled the water with soil dissolved in it. But what happens to the water itself? It seems to disappear. It changes from liquid water to water gas, or vapor. This is called **vaporization** (vay-per-ih-ZAY-shun). As the water changes to steam, it becomes pure.

The second step is to condense the water vapor back to liquid water. When the steam has been cooled and collected, it is pure water. It does not contain mud or minerals. Does it contain germs? How do you know?

You can distill water in your classroom. To see how you can get pure water by distilling, add about a teaspoon of salt and some food coloring.

Plan how you will cool the steam and collect the distilled water. What will happen to the salt? Will the distilled water taste salty? Will it be colored?

Swimming and Playing in the Water

Playing in the water can be great fun, if . . . .

Can you complete the sentence? Probably the first ending should be *if you can swim.* Another should be, *if the water is clean.* A third should be, *if there is an older person with you.*

Be Sure You Can Swim

One of the first things that a beginning swimmer should learn is how to float. You can float facing down or facing up. If you lie on your back and keep your nose and mouth above the water, you can float for some time. Since the water holds you up, all you have to do is to learn how to move your arms and legs and to breathe without taking water into your lungs.

If you do not know how to swim, a good swimming instructor or an adult who is a good swimmer can teach you in a few lessons. Then by practicing you can become a good swimmer. A safe swimmer is one who never takes chances.

In the picture below are five rules for safety in the water. Why are these good rules? Be sure to remember them and to obey them.

WATER SAFETY RULES
1. Never swim alone.
2. Never jump or dive when you do not know how deep the water is.
Never show off in the water.
Wait at least an hour after meals before going into the water.
5. Stop swimming before you get too tired.

Be Sure There Is an Adult with You

A careful swimmer never swims alone. No matter how good a swimmer you are, there is always a possibility that something may happen to you. Sometimes very good swimmers get cramps in their arms or legs and are not able to move them. Sometimes they get cramps in their stomachs and cannot straighten out. When this happens they may not be able to swim or float. They must have help. If they are alone they may drown.

If you are a beginner, be sure you are safe while you learn. Never try to learn by yourself. Never go swimming when the only person with you cannot swim either.

Try hard to become a good swimmer. Nearly always the safest swimmers are the good swimmers.

Always make sure there is a grownup with you when you go swimming. Why is this important?

Be Sure the Water Is Clean

There are many ponds and lakes where the water is not fit for swimming. The water is dirty. It has germs in it that will cause swimmers to become sick. Just as the health department in your city or county checks drinking water for germs, it also checks public swimming places. If you swim in a public place you can usually be sure that the water is clean. People who have their own backyard swimming pools must be very careful to keep the water clean and to kill all the harmful germs that get into it. You can get skin diseases, and some other diseases, very easily if you swim in water that is not properly cleaned.

Using What You Have Learned

1. Plan a visit to a place where the water is treated so that it is safe to drink. Find out how it is treated.

   Have your class plan a list of questions that they would like to have answered. Perhaps someone in your class can interview one of the scientists. Your class might try to write their own report called "Meet the Scientist."

2. Show whether it is easier to float in salt water than in fresh water. Fill a pot with water from the faucet. This stands for a lake. Put a fresh egg into the "lake." What happens to the egg?

   Now stir in a teaspoon of salt to the water. You now have an "ocean." What happens to the egg?

   What does this tell you about floating in lakes and in oceans?

Fire Safety

Fire under control is one of our best friends; out of control it is one of our worst enemies. Each year, fires destroy more than one billion dollars' worth of property. This is about the amount of money it would take to build homes for 250,000 people. Would this be enough to build homes for all the people living in your city or county?

During one year, more than 6,000 people were killed by fires in their homes. In fact, a common cause of injury to children of your age group is fire or objects that have been heated by fires. If you have made the survey on page 265, you can check it to see how many of your classmates may have been injured by fire.

What Does Fire Need to Burn?

We know that fire causes many accidents. If we are going to do a better job of controlling fire, we must find out all we can about it.

A fire needs certain things from the air to burn. You can show this by doing the following experiment. Be sure you do this experiment only when a teacher or other adult is watching.

EXPERIMENT

Does Fire Need Oxygen from the Air to Burn?

What You Will Need

4 candles
4 pieces of metal
matches
4 jars (small jar, pint jar, quart jar, and very large jar)

How You Can Find Out

1. Melt the end of a candle so that it will stand on a piece of metal.
2. Light the candle and lower the smallest jar over it. What happens? Why?
3. Stand three other candles on pieces of metal.
4. Lower the other three jars over the candles. You will need someone to help you do this. Be sure that you lower all three jars at the same time.
5. Time how long each candle burns.

Questions to Think About

1. Which candle went out first? Why?
2. Which candle went out last? Why?
3. How long did each candle burn?

You have seen that a lighted candle goes out when it is shut up in a jar. It will go out as soon as it uses up most of the oxygen in the jar. It will burn longer in a quart jar than in a pint jar because there is more oxygen.

What do you think would happen if you lowered a lamp chimney over a lighted candle?

Is it better to have air come in at the bottom or the top of the chimney? You can find out.

EXPERIMENT

Is the Flame Brighter If Air Comes In at the Bottom or at the Top of the Chimney?

What You Will Need

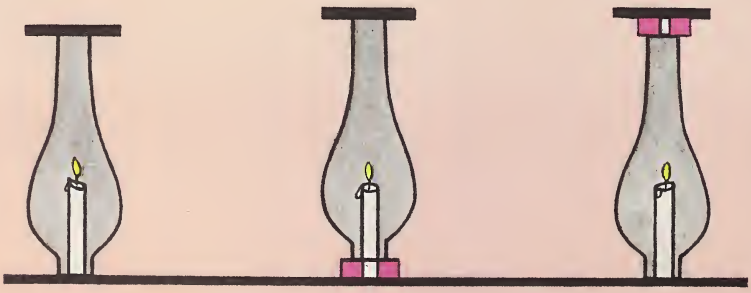
3 candles
piece of metal
3 lamp chimneys
4 pieces of wood

How You Can Find Out

1. Stand three candles on a piece of metal.
2. Cover one lighted candle with a lamp chimney.
3. Put the second chimney over the second candle, resting the chimney on two pieces of wood so that air can come in at the bottom.
4. Cover the third lighted candle with the third lamp chimney.
5. Put two pieces of wood on the top of the third lamp chimney.
6. Cover the top of each chimney with a piece of metal.

Questions to Think About

1. Which candle burns the brightest?
2. How does the air get into the chimney?



The fact that fire needs air should help you think of ways to make a fire burn more brightly. Why do you sometimes fan a campfire to make it burn better? Why is it dangerous to build a fire outdoors on a windy day?

You have found that a candle flame goes out when there is not enough oxygen. This fact should help you think of some ways to put out a fire.

Can you explain why a fire can be put out if it is covered with sand? Can you give a good reason for smothering a small fire with a heavy blanket or with a rug?

Next time you are in a restaurant, movie theater, or department store, notice how many different ways have been provided to put out fires. How does each of these ways work?

How Is Fire Started?

Rubbing things together can cause heat. You can prove this by rubbing your hands together or by rubbing your fist across your desk. You can heat an eraser by rubbing it hard on a piece of paper for a minute or so.

If you rub some things hard enough and long enough, you can cause enough heat to start a fire.

Long ago, the Indians started fires with a bow and drill. When the Indian pulled the bow back and forth rapidly, the end of the drill and the piece of wood became very hot. The Indian had some broken-up dried leaves, or something else that burned easily. He placed them around the end of the drill, and they would soon catch fire.

When an astronaut's capsule hits the atmosphere upon returning to the earth, the metal of the capsule gets very hot. It gets hot because the air molecules rub against its surface rapidly. It gets so hot that it would burn up if it were not slowed down. Do you know how scientists slow it down? How can you find out?

There is another way that fires start. A pile of oily rags or papers will produce a small amount of heat. If this heat cannot escape easily, the pile may become very hot. The rags may become so hot that they will burst into flame. This could happen in your home if a pile of oily rags or papers were stored in your cellar or attic. Many fires have started this way. They have burned homes and other buildings. These fires could have been prevented if someone had been more careful.

How to Put Out Fires Safely

You have learned that it takes three things to make a fire. First, there must be something to burn. Second, there must be oxygen. Third, the material must be heated. If you want to put a fire out, it is important to know what fires need to burn.

When you want a fire to die out by itself, you sometimes let all the material burn up. When this happens, there is nothing left to burn and the fire goes out. This is what happens to a fire in a fireplace if you do not keep adding wood or coal to it.

Fires need oxygen from the air in order to burn. Fires go out if they do not get enough air. You saw this happen when you covered a candle flame with a jar cover. This also happens when you cover a fire with sand or soil. You have probably seen a fire put out with water.

Water helps to put out fires in two ways. The water and steam cut off the air which the fire needs. The water also cools the burning material. This keeps the material from burning easily.

We know that we must be careful to put out our campfires. All these ways can be used.

How Fire Extinguishers Work

You have seen fire extinguishers in your school and in other places. They should always be handy and in good working order. There are several kinds of fire extinguishers.

One kind of fire extinguisher is filled with water and baking soda. Inside it there is a little bottle near the top. The bottle is filled with **acid**, which is a liquid. This acid is something like vinegar, but stronger. It is so strong that it would burn your skin if you touched it.

When the fire extinguisher is turned upside down, the acid in the bottle mixes with the baking soda and water. This makes a gas called carbon dioxide. It collects at the top of the tank and forces the water out through the hose. The water puts the fire out.

This kind of fire extinguisher can be used to put out small fires. If a house is on fire, a small fire extinguisher is not enough. The fire department is needed.

Can a gas be used to put out fires? Try the experiment on the next page to find out. *Be sure to have your teacher or another adult help you do this experiment.*

Can Carbon Dioxide Put Out a Fire?

What You Will Need

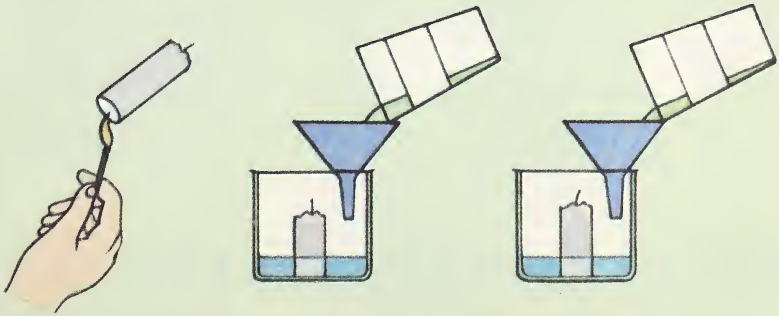
2 glass jars	half a cup of warm water	some vinegar
2 short candles	tablespoonful of baking soda	funnel

How You Can Find Out

1. Melt the bottom ends of the candles.
2. Stand one candle in each jar.
3. Pour a half cup of vinegar into one jar, using a funnel. Be careful not to wet the candle wick.
4. Light the candle. Does anything happen to the candle flame?
5. Pour the warm water and baking soda into the second jar. Do not wet the candle wick.
6. Light the second candle.
7. Pour a little vinegar into the second jar. Vinegar is an acid. When the vinegar mixes with the baking soda and water, bubbles of carbon dioxide form. What happens to the candle flame?

Questions to Think About

1. Why did the candle burn in the first jar?
2. Why do some fire extinguishers have baking soda, water, and acid in them?
3. What other kinds of fire extinguishers are there? What do they contain? How do they put out fires?
4. Why should water never be used to put out a fire started by electricity?
5. What kind of fire extinguisher should be used for an electrical fire? How does this extinguisher work?



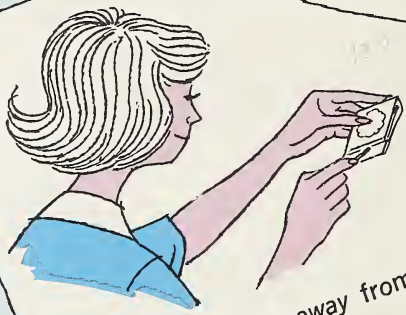
FIRE SAFETY RULES

DO

1. Use sand, ashes, or water to put out fires.

2. Know how to smother fires with a blanket or rug.

3. Put hot ashes in metal containers.

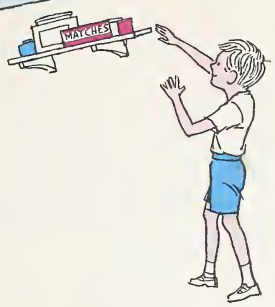


4. Strike matches away from yourself.

5. Keep oily mops and rags in a tightly covered container.

6. Know how to turn in a fire alarm.

DON'T



1. Don't leave matches where small children can get them.

2. Don't light bonfires unless a grown-up is with you.

3. Don't start a fire on a windy day.

4. Don't use kerosene or gasoline to start a fire.

5. Don't use liquid fuels to make a fire burn better.

6. Don't use matches or candles to light up dark places.

Fire Prevention

Fire is one of man's greatest helpers. But it can be a terrible enemy if it is allowed to get out of control. The best way to keep fires from causing damage is to keep them from starting where they are not wanted. This is what we mean by **fire prevention.**

Some children in your school may not know as much as you know about preventing fires. You may want to plan a fire prevention program for them. You can tell them some of the things you have learned about fire. You can tell them the rules that children must obey to prevent fires.

ABOUT "FIRE SAFETY"

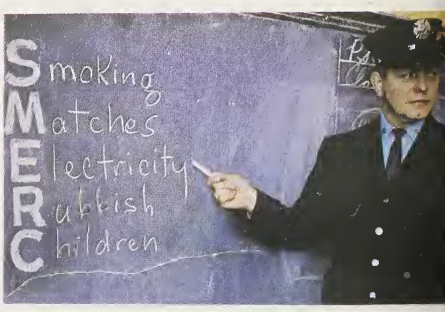
Just as bicycle safety and traffic safety are up to you, so is fire prevention. Thousands of lives and millions of dollars' worth of property could be saved each year if people observed some very simple rules. You will now learn what these rules are from members of the New York City Fire Department.

STOP
FIRES
smoking in bed
electrical defects
children + matches
cooking hazards
F.D. N.Y.
Foxy the Firefighter says:
BE FOXY... DON'T JUGGLE WITH FIRE
Fire Department, City of New York Robert F. Wagner, Mayor Edward Thompson, Fire Commissioner
10
Fire Safety
STOP FIRES
SAVE LIVES
FIRE PREVENTION
FIRE DEPARTMENT, CITY OF NEW YORK
WANTED
ANYONE GUILTY OF SENDING A FALSE ALARM
False Alarms Rob You!
STOP FIRES
SAVE LIVES
FIRE PREVENTION WEEK · OCTOBER 7-13

A visit to a classroom by firemen is an important part of a Fire Department's fire prevention program.

To start his demonstration, the fireman draws a triangle on the board. He writes the letters **H, O,** and **F,** one for each side of the triangle, and asks if anyone can tell him what the letters stand for. The letters stand for **H**eat, **O**xygen, and **F**uel. These are the three ingredients that make a fire. If you remove any one of these three ingredients, the fire will go out.

What causes a fire? Here you see five important causes listed. You can remember them by knowing what **SMERC** stands for. **S** is for *smoking* in bed, **M** is for playing with *matches,* **E** is for *electrical* fires caused by overloading of circuits, **R** is for *rubbish* such as oily or greasy rags, which ignite if kept in confined areas, and **C** is for *children* who are left alone and who may get into trouble.

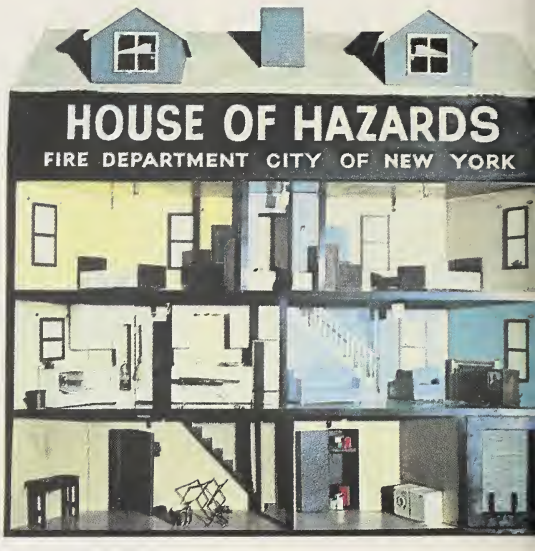


On the next page, you see the three classes of fires—**A, B,** and **C.** Before you put out a fire, you must know what kind of fire it is. Then you must know which fire extinguisher to use on the fire.

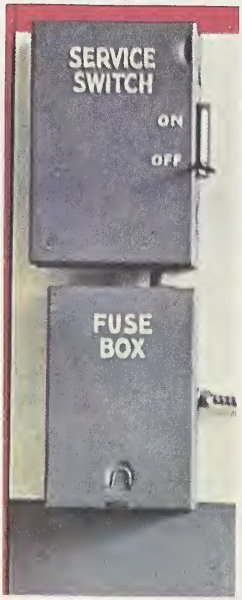
CLASS **A** FIRES
Paper, wood, cloth, rubbish.
Water puts out the fire by its cooling effect.

CLASS **B** FIRES
Burning liquids (gasolines, oils, paints, cooking fats).
Foam smothers the fire. Foam floats on top of the liquid, acting as a blanket. It keeps out oxygen. Carbon dioxide may also be used on this type of fire.

CLASS **C** FIRES
Live electrical equipment (motors, switches, appliances).
Carbon dioxide is used, because it does not conduct electricity.



The House of Hazards shows all the places where fires may occur in a house. Can you name these places? Can you tell what may cause fires in each of these places?



We use a great deal of electricity in our homes. Look at all the outlets in your home. There are wires carrying electricity to each of the outlets. If not used properly, electricity can be a destructive force. In these pictures, a fireman explains what happens when you overload an electrical circuit by using too many appliances.

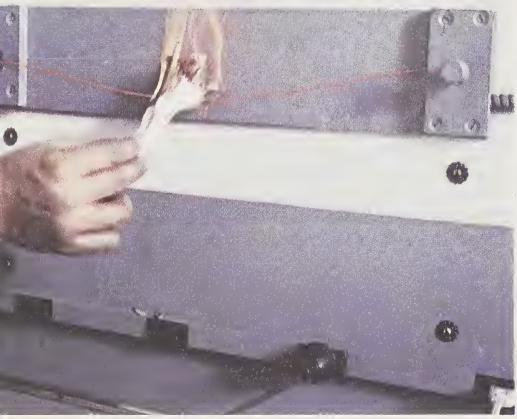
Every electrical circuit in your house or apartment is fused. Without the fuse, electrical current will not flow through the wires. Whenever a fuse is replaced, the electricity should **always** be shut off first, by pulling the lever to the *off* position.

Here you see the fireman plugging in three appliances.

Next, he also plugs in the toaster. Look at the lamp bulb and the fan. What do you see happening? Do the lights in your house dim when you use a toaster or a fan? Does your television picture shrink when the vacuum cleaner is in use? You may be overloading the circuit. Does your outlet look as though an octopus is plugged into it? You may be plugging too many appliances into one outlet.

Some people replace the fuses they have been using with fuses having a higher rating. Now let's see what happens to the wires in the walls when this is done.

The larger fuse allows more electricity to flow through the wires. But the wires are not able to take such a load, and they get very hot.



This is what happens when a piece of paper is touched to the wire. First smoke, then fire appear. In your walls, the hot wire burns through its insulation. The walls catch fire.

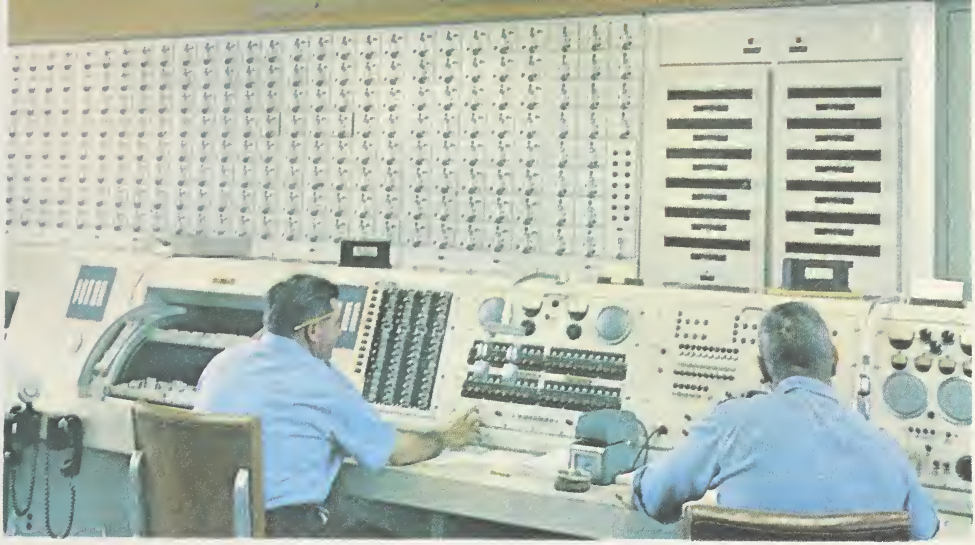
If you use the proper fuse, this will not happen. Instead, the fuse will blow (see fuse on right), shutting off the current. The wires will not become hot, and you have been warned that you have overloaded your circuit. Some homes have circuit breakers that act as fuses. Find out how a circuit breaker works.

YOUR NEW YORK CITY FIRE DEPARTMENT
0000
FIRE CAUSES
1 Fuses too large or tampered with
2 Overloaded wiring
3 Worn out wiring and equipment
4 Defective appliances
5 Do-it-yourself electrical work
6 Electric cords
7 'Octopus' outlets
SERVICE SWITCH
ON
OFF
FUSE BOX
INADEQUATE WIRING CAN CAUSE FIRES!
FIRE PREVENTION
1 Use proper size fuses
2 Don't overload wiring systems
3 Modernize old wiring systems
4 Have defective appliances repaired
5 Don't do your own electrical work. It's illegal
6 Have frayed or worn cords replaced
7 Eliminate 'octopus' outlets
THE BEST WAY TO ELIMINATE POTENTIAL FIRE HAZARDS IS TO HAVE A LICENSED ELECTRICAL CONTRACTOR MAKE SURE YOUR WIRING SYSTEM IS ADEQUATE
ROBERT F. WAGNER
MAYOR
EDWARD THOMPSON
FIRE COMMISSIONER
CITY OF NEW YORK

What should you do when, through carelessness or other means, a fire does occur? Immediately send a fire alarm, either by telephone or by fire alarm box.

The way to turn in a fire alarm is shown on the left. Lift up the guard; then pull down the handle inside. Wait at a safe distance from the fire for the engines to come and direct them to the fire. If you telephone, tell the operator the address of the fire and give your name and telephone number. Wait at a safe distance from the fire for the engines to arrive and direct them to the fire.

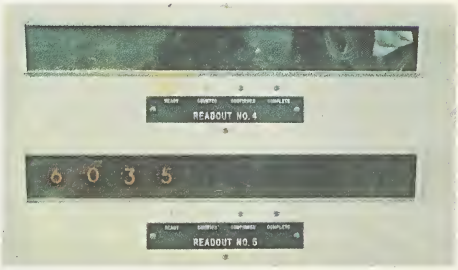
What happens when you send in the alarm? If you look at a fire alarm box, you will see that it has a number. The number on the box in the picture is 6035. When you pull the handle, the number 6035 is tapped out by means of a telegraphic system: first 6 taps, then 10 taps for 0, then 3 taps, then 5 taps.



This code is received at a Fire Department Communications Center. At the communications center, the men on duty listen as the alarm comes in.

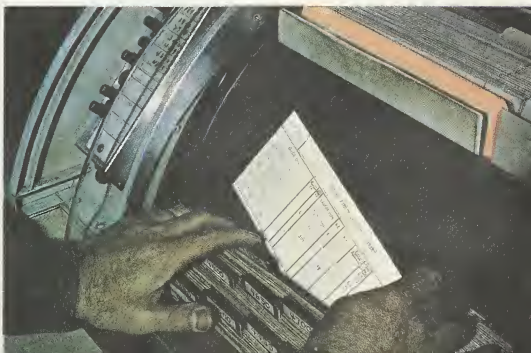
Here you see the alarm board, where all the fire alarm boxes are represented.

Meanwhile, the code number of the alarm box is also flashed on another board, so that there can be no mistake.



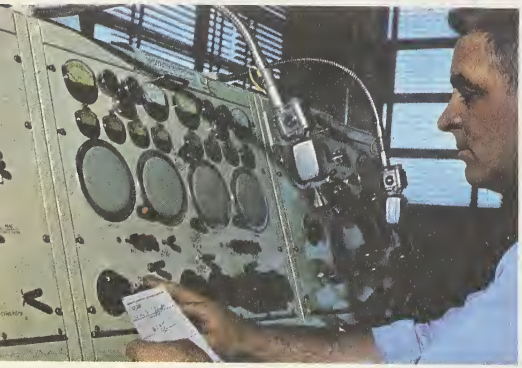
As soon as they identify it as 6035, they go to a card file and find the card for Box 6035.

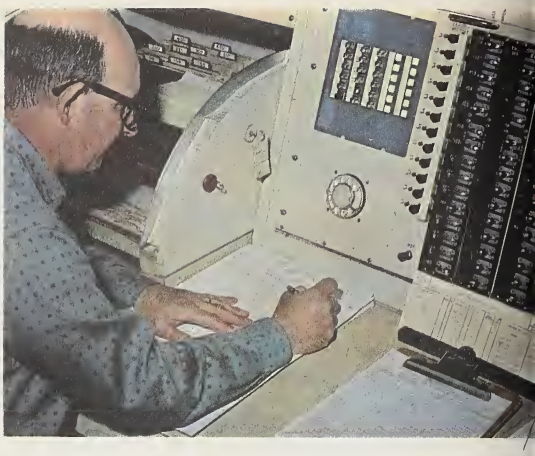
This card tells them where the fire alarm box is located and which fire companies are in the box's zone.



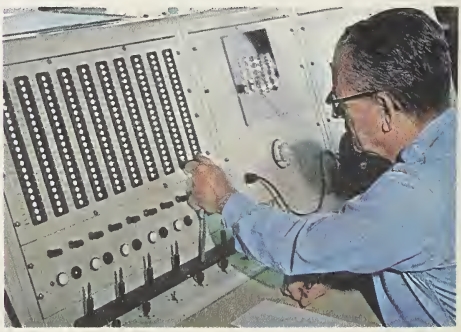
The dispatcher sends the alarm by a telegraph system to that zone. All the fire companies in the zone receive the alarm, but only those assigned in the area closest to Box 6035 respond.

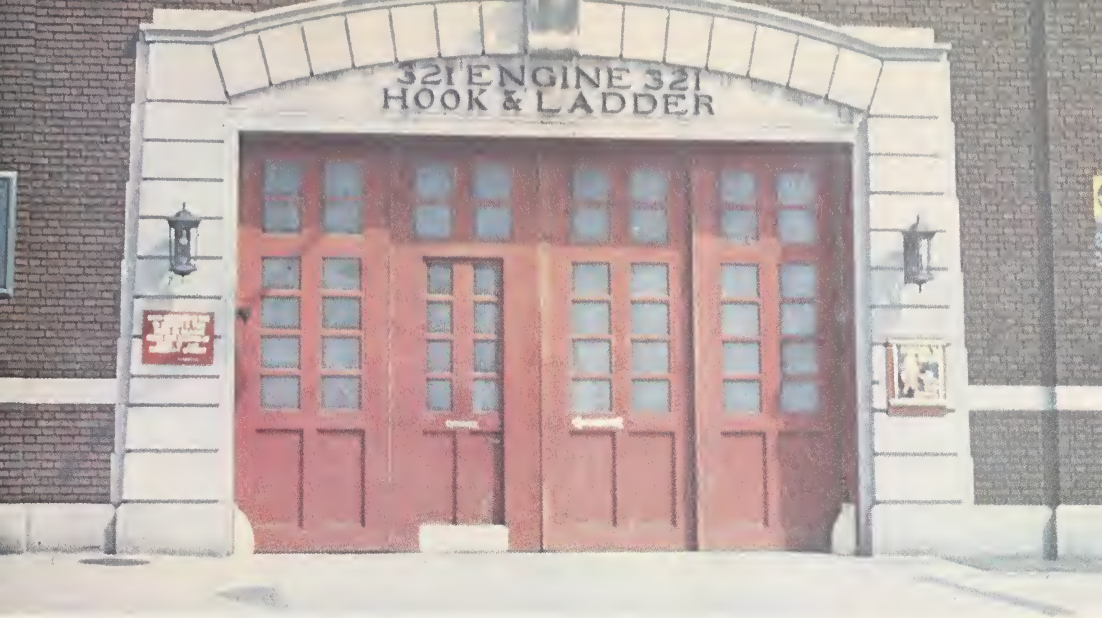
Then the dispatcher speaks by radio to the fire company.





If the alarm is telephoned to the communications center, the exact address of the fire is known. The dispatcher telephones the fire company nearest to the address to respond.





At the fire station, the fireman on house watch pulls out the card for Box 6035 to find out its address.

He calls out the address as the firemen slide down the poles and get ready to leave.

In a matter of seconds, the firemen are ready to go. In minutes, they will be at the scene of the fire. By this time, the communications center is in radio contact with the engines responding to the fire.

It takes only a few seconds for a fire to start, and just a few minutes for the firemen to get to the scene. But in that short time, lives and property could be lost forever.

Most fires can be prevented. That's your job. **Fire prevention is up to you.**

Using What You Have Learned

1. The fire department in your town saves many lives each year by putting out fires. Plan a visit to a fire station to find out how firemen get ready for their job. How do they plan their job so that no time is wasted in getting to a fire? How do they care for their equipment?
2. The fire drill in your school might save your life if a fire breaks out. Can you tell why? What rules are you expected to follow during a fire drill? Why are these rules needed?
3. Plan an exhibit to show what you have learned about fire. Show containers for materials that burn easily. Show some fireproof materials. Show pictures you have made of fire extinguishers and other ways of putting out fires. Make posters of rules for fire prevention.
4. Every year our nation suffers great losses because of forest fires that destroy lumber, homes, wildlife, and even human life. Make a report on ways to prevent forest fires and ways that forest fires are discovered and fought. A number of pupils may work together on this project.
5. Suppose that you are going down a street and you see smoke coming out the front door of a house. Which of these things would you do first? Why?
   a. Rush into the house to look for children.
   b. Wait till a man comes by and tell him.
   c. Find a policeman and tell him.
   d. Call the fire department.
   e. Walk by and say nothing about it.
   f. Call, "Fire!" as loudly as you can.

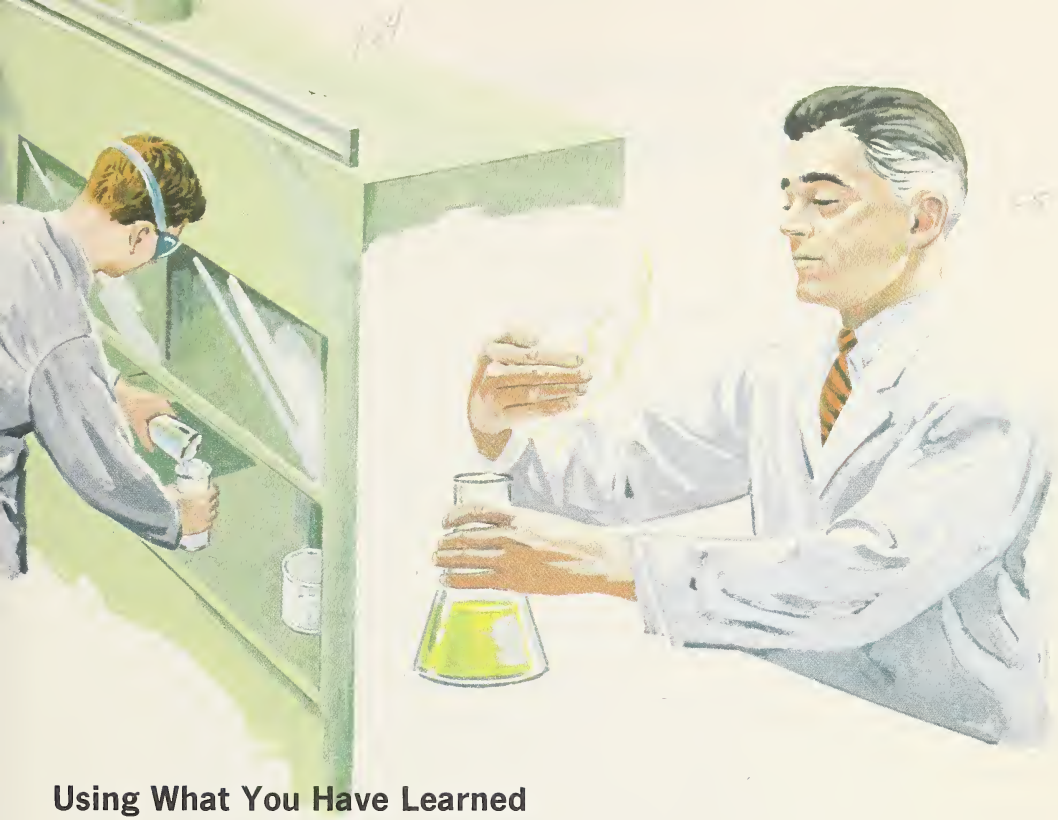
Safety in Science

You know that even ordinary household things can be dangerous if used carelessly. You must be careful to use them safely.

Always remember this rule: Never use any new material or equipment until your teacher has shown you how to use it properly and safely.

Now look at the pictures showing children doing science experiments and scientists at work. See how each person is working safely.

Can you tell what safety rules are being observed by the children and the scientists shown?



Using What You Have Learned

1. Make up a set of safety rules to follow whenever you do science experiments in your classroom or at home. Are there any ways in which your safety rules for home and those for your classroom might be different? Print your rules on a large piece of paper and hang them up in your classroom.

2. Send letters to large companies such as E. I. DuPont de Nemours in Wilmington, Delaware, and General Electric in Schenectady, New York. Ask about their safety programs for scientists and other workers.

WHAT YOU KNOW ABOUT
Safety and Science

What You Have Learned

Children have accidents most often when they are playing. They have many different kinds of accidents. Some children have accidents with their bicycles. In order to ride your bicycle safely, you must obey all the safety rules and check your bicycle regularly to make sure it is in good condition. If you must ride your bicycle at night, you should wear light-colored clothing and have a headlight and a taillight on your bicycle.

Unsafe drinking water can cause you to become very sick. You can make water safe to drink by filtering it to take the dirt from it and then boiling it to kill the **germs.** Germs can also be killed by adding **chlorine** to the water. But even water that is safe to drink may not be pure water. Water must be **distilled** to be made pure. There are no plants, animals, or minerals in pure water. Playing in water can be great fun if you can swim, if the water is clean, and if there is an older person with you.

Fire that is out of control can cause many serious accidents. If you want to control fire, you must know what things a fire needs when it burns. You have learned that it takes three things to make a fire. There must be some material to burn, there must be oxygen present, and the material must be heated. The best ways to keep uncontrolled fires from causing damage is to prevent them from happening.

You should never use any new materials or equipment until your teacher has shown you how to use them. If you follow this rule, you can prevent accidents from happening in the classroom.

Checklist of Science Words

Here are some science words you read about in this unit. Can you tell what you have learned about each one?

acid	distill	germs
chlorine	fire prevention	

Another Survey

One class took a survey to find out what accidents happened most often to boys and girls. Look at the master list they made up. Now, number your notebook page from 1 to 5. Next to each number, write the answer to each question below.

1. What accidents happened most often?
2. What accidents happened least often?
3. How many children were hurt by falls?
4. How many children were hurt in bicycle accidents?
5. How many children were hurt by fire?

MASTER LIST OF MR. CLARK'S CLASS

These accidents happened most often to boys and girls in our class.

1. Falls 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 30
2. Swimming Accidents 𝍸 𝍸 𝍸 15
3. Poisonings 𝍸 𝍸 || 12
4. Bicycle Accidents 𝍸 𝍸 𝍸 𝍸 𝍸 25
5. Fire Accidents 𝍸 𝍸 10

YOU CAN LEARN MORE ABOUT

Safety and Science

Unscramble the Letters

1. It is found in a fire extinguisher and is like very, very strong vinegar.
2. This kind of program can reduce serious accidents.
3. This is put in swimming pools and drinking water to kill germs.
4. The best way to keep fires from starting.
5. Water that has been boiled and condensed to make it pure.
6. We boil water to kill these living things.

1. DIAC
2. ECLIBYC EFASYT
3. RONICHLE
4. EFIR NTIRPEVEON
5. SLITELDID TRAWE
6. REMGS

You Can Visit

A water purification plant is a place where water is purified and tested.

If there is a water purification plant near your school, perhaps your class can arrange to visit it.

You should make up a list of questions to ask the scientists at the plant. You might ask them such questions as: "How do you filter the water? Where does the water come from? What chemicals do you add to the water to make it safe to drink?"

Make a Fire Extinguisher

You will need a milk bottle, a rubber stopper with a hole, a glass tube, a glass pill bottle, vinegar, water, baking soda, and a thin wire.

Mix the baking soda and water together and put them into the milk bottle. Fill the pill bottle with vinegar. Then wrap the wire around its neck. Push the glass tube through the hole in the rubber stopper. Stick the loose end of the wire firmly into the rubber stopper. Place the glass tube into the hole in the rubber stopper. Hang the pill bottle in the milk bottle. Press the rubber stopper tightly into place. You now have a fire extinguisher. When you turn it over, water will spray out.

You Can Read

1. *Safety in Family Living* by the National Commission on Safety Education, Washington, D.C.
2. *School Playground Safety* by State Department of Public Instruction, Lansing, Michigan.
3. *How to Make Your Home a Safe Place* by Metropolitan Life Insurance Company, New York, New York.
4. *Your Safety Handbook* by N. Dearborn and W. Andrews. Safety measures to observe at all times.
5. *Watch Your Step* by J. J. Floherty. How to avoid accidents.

Do You Remember?

Energy has many forms. One of these forms is *electricity*. Electricity can do work. Every one of the *electrons* and *protons* that make up an *atom* carries a charge of electricity. The electron carries a *negative charge* (—), and the proton carries a *positive charge* (+). Charges that are alike (++ or ——) push away from each other. Charges that are not alike (+— or —+) pull toward each other.

There are two kinds of electricity—*static electricity* and *current electricity*. Static electricity is electricity that is at rest on an object. Current electricity is electricity that moves along a path. Current electricity can be run through wires. It does a great deal of work that is useful to man.

Another form of energy is *sound*. Sound can do work. Sound is made when something *vibrates*. The number of times an object vibrates is called its *frequency*. *Pitch* is the name for how low or how high a sound is. The higher the frequency, the higher the pitch. We can also change the pitch of a sound by changing the thickness, the length, or the *tension* of the object. Musical instruments are a good example of the way thickness, length, and tension affect pitch.

Light is a form of energy. It can do work. When the energy of light strikes certain cells in your eyes, you can see. Light enters the eye through the *cornea*. From there it goes through an opening called the *pupil*. The size of the pupil is controlled by the *iris*. The light then passes through the *lens*. The lens *focuses* the light, first through a colorless liquid, and then onto the *retina*.

You have learned how scientists make *comparisons* to learn more about the many forms of energy. Making comparisons and knowing about the forms of energy enables weather scientists to *forecast* the weather more accurately. The weatherman must know how changes take place in *temperature, air pressure,* and *water vapor* in the air. He must also know what causes these changes.

Knowing about energy and its forms is not enough. Energy must be used safely. Energy can be very valuable to man, but the energy of fire, water, and moving objects can be dangerous, too. If you are careful, you can prevent accidents. For example:

1. To prevent bicycle accidents, you must watch and obey traffic signals. Obey the bicycle safety rules and check your bicycle brakes often.
2. To prevent accidents in the water, you must remember to swim only in clean water, and only when an adult is there to watch you.
3. To prevent fires, you must remember that fire needs air, heat, and material in order to burn.

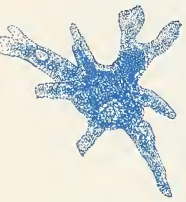
You have learned about different kinds of energy. You have learned how one kind of energy is captured by green plants, and how it is used by these plants and then by animals. You have learned about three important forms of energy: electricity, sound, and light. You have read about the forces that shape our weather, and lastly you have seen that it is important for you to learn to use energy safely.

Dictionary of Science Words

A

acid. The liquid used in a fire extinguisher. Acid is like vinegar, but it is much stronger. There are many other kinds of acid that can be used in many other ways. (p. 292)

ameba (uh-MEE-buh). A one-celled animal that is so small you cannot see it unless you use a microscope. Amebas live only in water. (p. 116)



anemometer (an-uh-MOM-uh-ter). A weather instrument used to measure the speed of the wind. (p. 239)

atoms. The particles from which all matter is made. (p.141)

B

barometer (buh-ROM-uh-ter). A weather instrument used to measure air pressure. One kind of barometer is the mercury barometer. (p. 244)

biologist (by-OL-uh-jist). A scientist who studies living things. (p. 115)

biology (by-OL-uh-jee). The study of living things. (p. 115)

blind spot. The part of the retina where there are no cones or rods. There is no vision at the blind spot. (p. 212)

bulb. The round, thick part of such plants as the onion and tulip. Bulbs grow in the soil and have food stored in them. (p. 73)

C

cell. A tiny unit of living matter. All living things are made of cells. (p. 105)

chlorine (KLOR-een). A chemical put into water to kill germs. (p. 285)

chlorophyll (KLOR-uh-fil). The green chemical found in green plants. Chlorophyll is used by these plants to make food. When the sun shines, the plants with chlorophyll can change carbon dioxide and water into glucose. (p. 62)

chrysamoeba (KRISS-uh-mee-buh). A tiny living thing that is often found in ponds. It makes its food by photosynthesis, as a green plant does. But it can also eat food that it does not make itself. In this way, the chrysamoeba is somewhat like an animal. (p. 112)

circuit (SER-kit). The unbroken path of an electric current. A circuit is made whenever electricity leaves a source and then returns to the same source. (p. 156)

closed circuit. An electric current that leaves a source and then travels along an unbroken path back to the same source. (p. 156)

comparison. A way of telling how things are alike and how they are different. (p. 2)

complicated animal (KOM-pluh-kayt-id). An animal with many different parts. (p. 116)

condensation (kon-den-SAY-shun). The changing of water vapor to liquid when the air is cooled. (p. 248)

conductor (kun-DUK-ter). A material that makes a good path for an electric current. Most metals are good conductors. (p. 149)

cones. Cells in the retina that help you see colors and small objects. (p. 210)

connective cells (kuh-NEK-tiv). Cells that connect other cells together. (p. 119)

controls. The things that you keep the same in an experiment. (p. 11)

cornea (KOR-nee-uh). The clear outside covering of the eye. Light enters the eye through the cornea. (p. 204)

current electricity (KUR-ent). The movement of electrons along a path or wire. In current electricity, the electrons enter an object, travel through it, and then pass out of it. (p. 149)

D

degrees. The marks on an instrument which are used for measuring. Degrees on a thermometer show you how hot or cold a thing is. (p. 247)

distilled water (dih-STILD). Water that is heated until it becomes water vapor, and then cooled until it becomes liquid again. Distilling removes the dirt and germs from the water. (p. 285)

dry cell. A metal can which makes an electric current. The can is filled with a material that is like paste. (p. 149)

E

echo (EK-oh). A sound that you hear more than once because the sound waves bounce back. (p. 189)

electricity (ih-lek-TRISS-ih-tee). A form of energy. Electricity can push or pull things. One kind of electricity is current electricity. Another kind is static electricity. (p. 22)

electromagnet (ih-lek-troh-MAG-nit). A piece of metal with a coil of wire around it. The metal becomes a magnet when an electric current flows through the coil. (p. 159)

electron (ih-LEK-tron). A particle that moves around the nucleus of an atom. The electron has a negative charge. (p. 141)

energy. The ability to do work. There are many kinds of energy, such as electricity, heat, light, and sound. (p. 22)

energy in action. Energy that is doing work. (p. 25)

euglena (yoo-GLEE-nuh). A tiny living thing that is often found in ponds. It can swim, like animals, but it can also make its own food, like green plants. (p. 112)

evaporation (ih-vap-uh-RAY-shun). The escape of water molecules into the spaces between the air molecules. (p. 247)

experiment. The scientist's way of seeking proof for ideas, by measuring and comparing things and by using controls. (p. 2)

experimental factor (ik-sper-uh-MEN-tul FAK-ter). The one thing that is different in an experiment. (p. 11)

F

Fahrenheit (FAR-un-hyt). The scale on some thermometers. (p. 247)

fertilizer (FER-til-yz-er). A material that is put into the soil to help plants grow better. Fertilizers are rich in important minerals. (p. 94)

fire prevention. Making sure that fires do not start in places where you do not want them. (p. 296)

focusing (FOH-kuss-ing). The moving of a lens to change the direction of the light. Focusing the light helps the eye to see objects more clearly. (p. 206)

force. A push or a pull on an object. Energy is needed to produce a force. (p. 28)

forecast (FOR-kast). To tell what the weather will be like. (p. 224)

fovea (FOH-vee-uh). The place near the center of the retina where there are only cones. (p. 211)

frequency (FREE-kwen-see.) The number of times that an object vibrates each second. (p. 175)

friction (FRIK-shun). The rubbing of one thing against another. Friction produces heat. (p. 44)

fungi (FUN-jy). Plants that are not green and which do not have any chlorophyll in them. Fungi do not make their own food. (p. 79)

fuse (fyooz). A piece of metal which opens a circuit when too many electrons are going through the circuit. (p. 164)

G

germ. A tiny living thing that can cause disease. (p. 281)

glucose (GLOO-kohss). The sugar that is made by plants during photosynthesis. (p. 64)

gravity (GRAV-ih-tee). The force that pulls things toward the earth. (p. 37)

H

humus (YOO-muss). Plant and animal material that has decayed. Humus adds minerals to the soil. It helps the soil to hold more water and keeps the soil from becoming dry and hard. (p. 91)

hydra (HY-druh). A tiny simple many-celled animal with tentacles which is found in streams and ponds. The hydra gets its oxygen from the water. (p. 118)

I

instrument (IN-stroo-ment). A tool that scientists use, such as a barometer or microscope, to measure and do other things more accurately. (p. 2)

insulator (IN-suh-lay-ter). Any material that does not allow electricity to move freely through it. Rubber and glass are insulators. (p. 150)

iris (EYE-riss). The circle of color in the eye. The iris is a muscle which controls the amount of light that enters the pupil of the eye. (p. 205)

L

lens (lenz). A part of the eye between the pupil and the retina. Light enters the eye through the pupil and is then focused by the lens onto the retina. (p. 205)

lever. A simple machine that can be used to lift or move an object. A lever is a bar which you push down on one end so that you can raise an object at the other end. A crowbar is an example of a lever. (p. 31)

life activity. One of the things plants and animals do to stay alive, such as using food and oxygen, producing more living things like themselves, and getting rid of wastes. (p. 104)

life history. The way in which each plant and animal lives and grows. (p. 83)

light. The form of energy that lets you see. (p. 221)

light receiver cells. The rods and cones in the retina of the eye. These cells receive the light after it has traveled through the lens. (p. 210)

loam. A type of soil that is made of sand, clay, and humus. Loam is the best soil in which to grow plants. (p. 91)

M

matter. Anything that fills space. (p. 140)

mechanical energy (muh-KAN-ih-k'l). The energy of moving things. (p. 25)

mercury barometer (MER-kyoo-ree buh-ROM-uh-ter). A weather instrument used to measure air pressure. When air pressure increases, mercury is pushed up. When it decreases, mercury goes down. (p. 244)

molecules (MOL-uh-kyoolz). The very small parts that make up the air. Most things are made of molecules. (p. 231)

muscle cells. Long, stringy cells that are held together by connective cells. (p. 120)

N

negative charge. The — charge of an electron. A negative charge pulls toward positive proton charges and pushes away from other negative electron charges. (p. 142)

nerve cells. Cells that receive messages and then send the messages to other cells. (p. 119)

neutron (NOO-tron). One of the particles in the nucleus of the atom. The neutron has no charge. (p. 141)

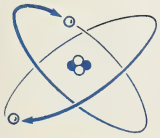
O

open circuit (SER-kit). An electric current that leaves a source but does not come back to that source. (p. 156)

opaque. A word describing any material through which light will not pass. (p. 202)

ophthalmic surgeon (ahf-THAL-mik). A doctor who operates on the human eye. (p. 214)

orbit (OR-bit). In the science dealing with electricity, this term refers to the path that an electron makes around the nucleus of an atom. (p. 144)



P

parallel circuit (PAR-uh-lell SER-kit). A circuit in which all the lights do not go out when one of the lights goes out. They do not all go out because the circuit is not broken. (p. 156)

photosynthesis (foh-tuh-SIN-thuh-siss). The making of food, by green plants, from carbon dioxide, water, and sunlight. (p. 63)

pitch. How high or how low a sound is. (p. 183)

porous (POR-uss). Full of tiny air spaces and therefore able to absorb sound waves. (p. 191)

positive charge. The + charge of a proton. A positive charge pulls toward negative electron charges and pushes away from other positive proton charges. (p. 142)

proton (PROH-ton). One of the particles in the nucleus of an atom. The proton has a positive charge. (p. 141)

pulley (PULL-ee). A simple machine that is used for lifting objects. It is made with a wheel and a rope. By pulling one end of the rope, an object tied to the other end of the rope can be lifted. (p. 33)

pupil. The small black circle in the eye, really the space inside the eye. The size of the pupil is controlled by the iris. (p. 204)

R

rain gauge. An instrument used by weather scientists to measure the amount of rainfall. (p. 224)

reflected waves. Waves which are bounced back. An echo is the result of reflected waves. (p. 188)

retina (RET-ih-nuh). The inside part at the back of the eyeball which has cone cells and rod cells in it. The retina receives the light from the lens. (p. 209)

rods. The cells in the retina that help you to see better when the light is dim. (p. 210)

S

scale. All the evenly spaced marks along an instrument, which are used for measuring. (p. 247)

series circuit (SEER-eez SER-kit). A circuit in which all the lights go out when one of the lights goes out. They all go out because the circuit is broken. (p. 156)

short circuit (SER-kit). A circuit that has been broken. In a short circuit, the wires touch and the electrons flow along a shorter path. (p. 161)

simple animal. An animal with few parts, such as an ameba or a hydra. (p. 116)

sound. A form of energy. Sound is heard when an object vibrates fast enough. (p. 22)

soundproofing materials. Porous materials that are used to absorb and control noises and echoes. (p. 192)

sound waves. The waves that travel through material and cause you to hear. (p. 177)

static electricity. Electricity that is made by friction. Static electricity does not move along a path. It jumps from one object and then rests on the object on which it lands. (p. 148)

stored energy. Energy that is not doing work. A match has stored energy. (p. 25)

survey (SER-vay). A way of looking for information in different places and keeping a written record of what you find. (p. 109)

system of classification. A way of sorting things into groups so that you know where each thing belongs. Scientists use the binomial system to classify living things. (p. 122)

T

tension (TEN-shun). The tightness or looseness of any object that can be stretched. A change in tension can make a vibrating object change its pitch. (p. 186)

tentacles (TEN-tuh-kulz). Long, stringy arms used for feeling, holding, or moving. The hydra is an animal that has tentacles. (p. 118)

translucent. A word describing any material that lets light enter and then scatters it. (p. 202)

transparent. A word describing any material that allows light to pass through it freely. (p. 201)

U

ultrasonic sound (ul-truh-SON-ik). A sound that you do not hear because the object is vibrating more than 20,000 times each second. (p. 176)

V

vaporization (vay-per-ih-ZAY-shun). The changing of a liquid into a gas. In water vaporization, the water changes into a gas called water vapor. (p. 285)

vibrate (VY-brayt). To move back and forth quickly. (p. 173)

vibration. A quick back-and-forth movement. (p. 173)

W

water vapor. Very tiny particles of water in the air. You cannot see water vapor because it is a gas. (p. 224)

weather station. A place where scientists forecast the weather. They use instruments there to measure such things as temperature, air pressure, rainfall, and the speed of the wind. (p. 224)

weed. A plant that grows where you do not want it. (p. 81)

wind. Air that is moving. (p. 229)

work. Moving something by pushing or pulling it. When something is being moved, work is being done. (p. 22)

Dictionary of Scientists

Here is a list of the scientists you have read about in this book.

Aristotle (AR-iss-tot'l). A famous Greek scientist. His studies prepared the way for other scientific discoveries. He gave his own wide knowledge and experience to the scientists who came after him. (pp. 4, 12)

Boyle, Robert. The English scientist who discovered that sound waves cannot travel where there is no air. (p. 176)

Cooper, Irving S. A medical doctor who found that he was able to help patients with Parkinson's disease by freezing portions of their brains. (p. 214)

Fahrenheit, Gabriel Daniel (FAR-un-hyt, GAY-bree-el DAN-yell). The German scientist who made up the scale called the Fahrenheit scale, now used on certain thermometers. (p. 247)

Galilei, Galileo (gal-uh-LAY-ee, gal-uh-LAY-oh). An Italian scientist who was one of the first men to seek experimental proof for his ideas. (p. 4)

Ingen-Housz, Jan (ING-un-howss). The Dutch scientist who did the first research in photosynthesis. (p. 64)

Joule, James. The English scientist who showed that when one form of energy is changed into another, no new energy is created and no old energy is destroyed. (p. 26)

Kelman, Charles D. An eye surgeon who has experimented with cryosurgery (cold surgery). (p. 214)

Leverrier, Urbain (leh-vehr-ee-AY, ur-BAN). The French scientist who made the plan for the first international telegraph system. (p. 227)

Lincoff, Harvey, and associates. The medical doctors who first used cryosurgery (cold surgery) to heal detached retinas. (p. 214)

Lining, John (LYN-ing). A medical doctor who was the first to keep careful and correct records of the daily weather where he lived in America. (p. 225)

Linnaeus, Carolus (lih-NEE-uss, KAR-uh-luss). The Swedish scientist who made up the binomial system of classification for all plants and animals. (p. 128)

Morse, Samuel F. B. The American scientist who, in 1837, invented the telegraph. (p. 226)

Potts, William L. A traffic engineer who set up the world's first four-way traffic-signal tower. (p. 266)

Rabinowitz, Eugene. A botanist whose study of green plants may some day help scientists to make photosynthesis happen without the use of plants. (p. 65)

Reichelderfer, Francis W. The former United States chief weatherman whose work helped the U.S. Weather Bureau offer many new services in weather forecasting. (p. 228)

Volta, Alessandro (VOHL-tah, ah-leh-SAHN-droh). The Italian scientist who built the first electric cell. (p. 150)

Checklist of Science Activities

Here is a list of some things you can learn to do as you read this book. At the end of each unit there are four pages that tell you other things you can do.

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